LEARNING LESSONS The past 40 years have seen the implementation of unattended train operation on an increasing number of metros, with some good results. However, it is important to take a systems approach if serious mistakes are to be avoided.

It is now 40 years since I wrote an article in Railway Gazette International discussing the potential for fully-automated operation of metro lines (RG 10.73 p382). Those four decades have seen the gradual adoption of driverless metros, using what is now termed Unattended Train Operation, but it has been a chequered path, with failures as well as successes along the way.

I believe that it is time to reflect on my original theses and consider how UTO has been applied in practice, in the hope that cities adopting automation in the future can learn from experience and not fall into the same traps.

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By the early 1970s, the concept of Automated Guided Transit was becoming increasingly popular in airports, universities and urban business districts. Commonly known as peoplemovers, these systems used short trains without attendants, mostly operating on short self-contained shuttle lines. Surely the next step would be an automated metro, I suggested.

Although the public transport sector may have been using computers for financial management, or holding maintenance data, metro operators seemed sceptical about fully-automated trains without crews. They responded that trains must have an attendant because of the need to cope with special or unforeseen events, citing the potential fears of passengers in trains without crews, and pointing out there were legal requirements on crew sizes in some countries.

The steadily shrinking crew

Looking back to the end of the 19th century, the earliest metro trains were operated with a driver, or motorman, plus one conductor per car to open and close the doors and supervise boarding. With the invention of train-lined door controls, crews could be reduced to the driver and a single conductor who operated all the doors and supervised passenger movements. Two-person crews became the norm for the next half century.

Increasing pressure to reduce operating costs, coupled with a labour shortage in Germany, led Hamburg to introduce one-person operation in 1957. The driver opened and closed the doors on eight-car trains up to 112 m long, with passengers supervised by an attendant on the platform, later using CCTV from a remote control centre. This was followed elsewhere by driver-only operation of trains up to 10 cars or 230 m long, notably on BART in San Francisco which opened in 1972.

As is the case for all systems that can be automated on an incremental basis, such as manufacturing or construction, the final step is the most complicated — elimination of the ‘last crew member’. That requires the automated systems to cope with all expected and unexpected events. Hence the title of my 1973 article: ‘Rapid transit automation and the last crew member’. That requires the automated systems to cope with all expected and unexpected events. Hence the title of my 1973 article: ‘Rapid transit automation and the last crew member’. That reflected on the obstacles to the removal of the train operator and considered possible methods to resolve them.

The article also reviewed the main justifications for the introduction of UTO, or Automatic Train Operation.
as it was often referred to at that time. These included the low cost of offering a high-frequency service all day, and not only during peak periods, even on lines with moderate passenger volumes, and the easy adjustment of train schedules to suit variations in demand. I pointed out that higher frequencies make interchange between lines much more convenient, helping the metro to attract people out of their cars or from other transport modes.

From attended ATO to UTO

Pioneered on London Underground’s Victoria Line in 1968, Automated Train Operation with computer-controlled driving under the oversight of a train operator was introduced on many new metros after about 1970, including BART. ATO provided more sophisticated control than manual driving, bringing the benefits of reduced energy consumption, lower wear and tear on the vehicles, and a more comfortable ride, amongst others.

But moving to UTO requires many more changes than ATO. Unattended trains must have fully controlled and protected tracks, centralised control and supervision of door operations at stations, and remote communication with the passengers in each train. Roaming attendants must be deployed who can intervene to solve unforeseen problems and emergencies along the line.

It should be noted that UTO is much easier to introduce on people-movers than conventional metros for two major reasons. Firstly, AGT is typically used in airports, medical complexes and university campuses, which have a more controlled ridership than open public transport services. And secondly, AGT lines have a totally different economic model, because they are typically financed and operated as integral parts of the airport or campus, like elevators, rather than through specially designated funds and passenger fares. Their operating ratio is not even computed.

The problems inherent in introducing UTO have been solved in different ways over the past 40 years1, and a comprehensive review was presented at a UITP seminar on Automated Metro in London last September. Statistics prepared by UITP’s Observatory of Automated Metro in 2012 show that the use of UTO has accelerated in recent years. Unattended trains were then operating on 41 lines in 25 cities2. However, the discussion about the reasons for their introduction and the Observatory’s projection of future growth in UTO merit further comment.

Some automated metros, such as Vancouver Skytrain, fully utilise the advantages of UTO by operating services at short headways throughout the day; train sizes and headways are adjusted in response to passenger volumes. On the other hand, some automated metros run large trains at long headways, and some even operate at significantly lower speeds than manually driven trains because their electronic controls extend, and sometimes even double, dwell times at each station. Not only are such lines not utilising the advantages of UTO, the lower speeds reduce line capacity and increase costs. These mixed results surely call for urgent attention if such costly mistakes are to be corrected and avoided in the future.

Characteristics of UTO

Automated metros differ from conventional lines in key technical, operational, economic and social aspects. The decision to introduce full automation should therefore be based on a broad systems analysis, comparing the advantages and disadvantages of UTO with those for operation with a crew member, with or without ATO.

As most transit operators know3, by far the greatest benefit UTO can bring is a drastic increase in service frequency without a comparable increase in costs, as the trains have no crews. For example, the cost of running one eight-car train is the same as four two-car trains. Thus, a service provided with eight-car trains every 10 min could be changed to two-car trains at 2½ min intervals with no impact on the investment or operating costs. Cutting the headway from 10 min to 150 sec offers a major enhancement in the attractiveness of the metro, as well as making passenger transfers to and from other lines or services much more convenient.

The second major benefit of UTO is the flexibility to tailor line capacity to suit variations in passenger demand during the day by adjusting the train size rather than the headway. Thanks to the remote control of yards and depots, and decoupling of the train service from crew assignments, this can ensure a better quality of service while delivering a very significant reduction in operating costs.

A third benefit is the easier response
København Metro operates short trains at a 3 min headway throughout the day. By contrast, Paris metro Line 14 uses larger fixed-formation trainsets and adjusts the headways to respond to variations in passenger volumes.

Track protection has been solved in several ways, such as the use of platform screen doors at stations or intruder detection systems that scan the track in platform areas. These are backed up using CCTV monitoring from the operations control centre.

Whilst most UTO has been introduced on new lines, recent years have seen the first conversions of existing lines, most notably the heavily-loaded Paris Metro Line 1 and Nürnberg U-Bahn Line U2. During the transition phase, both RATP and VAG went through periods of mixed operation of unattended and manually-driven trains on the same line. The introduction of UTO has boosted the capacity, reliability and efficiency of Paris Line 1, which is typically carrying more than 750,000 passengers per day.

Following experience with the conversion of Line 1 to UTO, Paris operator RATP has decided to follow suit with Line 4.

However, the Observatory has also identified a number of ‘serious problems’ which may result from UTO introduction. These can perhaps be more properly attributed to uncoordinated planning. I would like to consider three of the most serious issues: a failure to co-ordinate rolling stock design, the programming of train movements at stations, and the economics of investing in UTO when compared with prevailing labour rates.

Train design. The advent of the wide walk-through gangway has encouraged the design of articulated or permanently-coupled trainsets of up to five, eight or even 12 cars with a continuous interior. This certainly increases train capacity, facilitates passenger distribution and improves security, but it does pose operational limitations.

All-day operation of long trains may be justified on heavily trafficked lines, as found in Hong Kong, Beijing or Tokyo, but the walk-through design prevents operators from economically trading off train length and headways for a given capacity under UTO.

Successes and failures

According to the UITP Observatory, many of the problems that were considered obstacles to full automation 40 years ago have now been solved.

It has been possible to design metro lines for operation with variable-length trains to respond to varying passenger demand throughout the day. Changes in train lengths are common in many conventional metros, such as Hamburg, San Francisco and Washington. Among fully automated systems, Skytrain in Vancouver is a prime example of a fully automated metro where train lengths are varied between peak and off-peak periods to ensure that headways do not exceed 3 min.

Of course, UTO has its disadvantages. The biggest is probably the higher investment cost for the complex control and communication systems, plus platform screen doors and/or intruder detection at all stations. The increased technical complexity also requires more highly-qualified maintenance personnel.

The absence of an attendant on each train is seen as a negative in many cities, although this can be overcome by deploying roaming attendants on trains and stations to provide passengers with information and assistance as well as ensuring their safety and security.

Small and frequent trains are a hallmark of København’s automatic metro, and a similar formula has been adopted for the second line now under construction.
Several cities in Asia now have metro lines with UTO where six-car trains operate at 7½ min headways during off-peak periods. Thus the inflexible train design nullifies the advantage of frequent service. Using two- or three-car units to provide a higher frequency at the same cost would probably have been a better option.

**Dwell times.** Metro operators have always worked hard to minimise stopping time at stations, in order to increase operating speeds and line throughput. But on some metros the train stopping regime has been obviously designed by engineers, with extremely complicated safety controls which take many times longer than an attendant. On several recently-built metros, the slow braking as a train approaches a station is followed after the train comes to a stop by a delay of 6 to 10 sec until the doors open. After the passengers get on and off, the doors close, but the train then waits another 6 to 10 sec until it moves off. The introduction of UTO has increased the dwell time at each station from about 20 sec to almost twice as long.

This causes major losses. Calculations for an automated line in one Asian city with 16 stations show that the additional dwell time of 16 to 20 sec per station in each direction lengthens the overall cycle time by 9.6 min. As the line runs at 3 min headways during the peaks, this requires three or four more six-car trains than operating the same service with manually-driven trains and shorter dwell times. The ‘misuse’ of UTO has increased the investment and operating costs for the 18 additional cars, while lowering the operating speed by about 20% with a corresponding drop in line capacity.

**Staffing.** There have been suggestions that UTO is appropriate for developing countries, but this has to be questionable in the case of rapidly growing cities with very low wages. Rather than invest in sophisticated control systems which they must import and then maintain, such operators might be better advised to spend their limited funds on the construction of larger metro networks, given that the lower cost of labour would reduce the potential savings in operating costs.

There is also the issue of false benefits. Many reports describe the introduction of UTO as an innovation that successfully decreases energy consumption and vehicle wear and tear. In fact a driving regime for optimal energy use can also be implemented using attended ATO, as long as the operator does not need to intervene. Improvements in the provision of passenger information are also ascribed to UTO, but of course such improvements can be introduced regardless of train crew size.

**Taking a systems approach**

Fully-automated metro operation will undoubtedly continue to expand, but UTO should not be adopted simply because it is fashionable to do so. The choice of whether to automate needs careful planning and design through a systems engineering approach, considering the benefits to passengers, and particularly the anticipated service improvements.

These examples demonstrate the importance of involving the operator in the development of a UTO project. Indeed, the Observatory highlighted as a ‘hot topic’ at its seminars that ‘the operator’s involvement is key from the early stages of UTO line conception’. This is particularly important when it comes to optimising train speeds and ensuring a reliable service delivery model.

Following a proper systems approach can ensure that the rolling stock is specified to permit flexibility in train size, or that the automation is competently designed to minimise wasted dwell times which detract from train performance and decrease line capacity.

The case for automation is perhaps most beneficial on medium-capacity lines where UTO can make increased service frequency economically feasible. On networks like Tokyo, New York, Hong Kong and Moscow, where each train can carry up to 3 000 passengers, the ‘saving’ of one employee’s wages is negligible. By contrast, having an attendant on hand could be beneficial for communicating with the passengers and intervening where necessary.

The ability to provide a high-frequency service for moderate passenger volumes opens up opportunities for more diversified operation.

On networks with interconnected lines, such as New York, Washington, London or München, overlapping or interconnecting services could be operated. Having trains on different routes converging and diverging under automated control to serve a variety of origin and destination pairs would provide the necessary capacity on each section of line while reducing the need for passengers to transfer at interchange stations.

Even on stand-alone lines, UTO may make it possible to introduce skip-stop operation, which would raise the average speed on long routes with many stations.

References

The adoption of wide-gangwayed ‘walk-through’ trains has made it harder to adjust the capacity of automated metros by splitting and joining units.