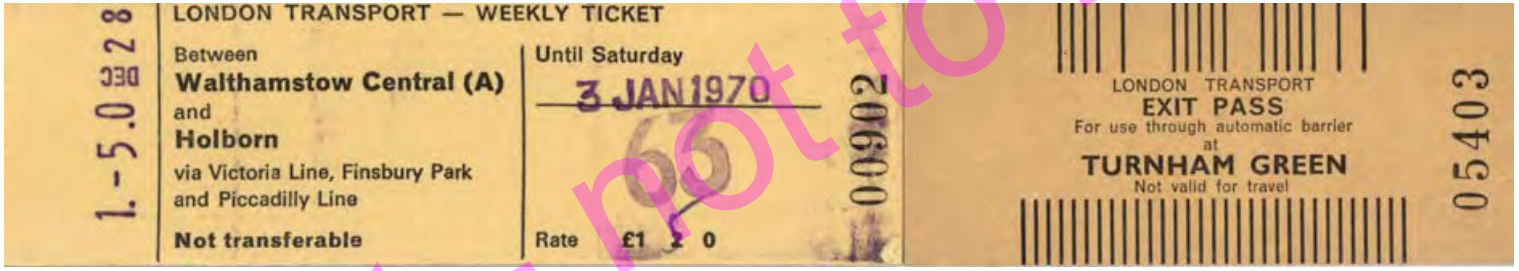
AUTOMATIC FARE COLLECTION

ON THE LONDON UNDERGROUND, AND LONDON BUSES

and Integrated TfL ticketing



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Introduction

Travel must be paid for by somebody and generally users pay the bulk of the day to day running costs of any transport organization, payments being made proportionately to the use that has been made. For many years this process has been governed by means of tickets, traditionally small pieces of card paid for before travel and authorizing one or more journeys. On railways this was a problematic process as tickets had to be prepared in advance, stored, accounted for, issued to passengers before travel and in many cases collected after travel to prevent reuse. On a busy system such as the Underground the bureaucracy involved was a major hindrance to the speed and convenience of the passenger journey, moreover costs were heavy. It was natural that as new technology became available the Underground authorities sought to automate the process of ticket issue and for several decades that was the focus of attention. Very slowly the technology for automatic ticket checking and passenger control via automatic gates became feasible in the late 1960s, but as first envisaged was impossible to adapt reliably to the complicated fares system. This was revisited in the 1980s when computer technology had evolved further. Technical evolution is now so advanced that tickets (we shall return to the meaning of that word) are now preloaded onto smartcards or even held centrally as bankcards can be accepted for access to the system and journeys charged when completed.

The situation on the buses evolved in a different way. Bus travel has predominantly always been paid for on (or shortly after) boarding vehicle and declaring and paying for the journey at that point. Tickets were issued upon payment, initially some form of printed card but in later years a paper ticket printed by machine at the time. Mechanical machines were expensive to purchase and maintain and cash management was problematic. Season tickets were not unknown but were a small percentage of sales. The system was simple and while it could (with some effort) be improved to cover journeys requiring a change of vehicle it was not easily adaptable to meet the rising clamour for integrated ticketing and with universal conversion to one-person operation boarding delays began interfering with running time and service reliability. Those running bus services in large cities, an in particular in London, also looked for technical solutions but and various trials took place. We shall turn later to that magical point where objectives were so much aligned that a single solution was found for bus and rail.

Before delving too deeply into Automatic Fare Collection it will probably be helpful to examine the ticket system employed, although this is not the place to provide the full historical treatment of ticket and ticket machine history, so only relevant developments will be mentioned and by and large unsuccessful experiments are ignored.

Chapter 1.
The Origin Of The London Underground Ticket System

Tickets on the Early Underground Railways

The earliest parts of the Underground were the systems of the Metropolitan and Metropolitan District Railways, built mainly in Victorian times. These railways employed exactly the same ticket system that the main line companies used. This was the so called 'Edmondson Card' System where a standard-sized ticket containing full details of the journey to be made was issued to the passenger from the ticket office. The ticket clerk selected the ticket from the appropriate ticket tube (or rack) and dated it at one end in a special press at the time of issue.

A typical Met Railway ticket office with very large numbers of tickets in stock, mostly with small numbers of sales.

Ticket issuing was naturally slow and the number of different denominations of tickets very large, with every station having to stock the whole range of tickets to every other station on the railway, or on neighbouring railways with which through booking arrangements were in force. This already potentially large range of tickets had then to be multiplied by the different types of ticket available (for example single, return, privilege, animal, soldier's leave, and so forth). These types of tickets were known as point-to-point tickets and are still generally employed in one form or another by the main line railways, though they are no longer of the 'Edmondson Card' type.

On the underground railways, a slight reduction in the size of the ticket stock was made by combining tickets for particular stations where the fare for both was the same and they were on the same route. One reason why railways were keen to collect used tickets was that it was the only way to determine which journey had actually been made when tickets were available to more than one station, and for accounting and management information purposes this was important (as well as reducing the temptation for passengers to try and use a ticket more than once).

When the electric tube lines opened in the period 1890 to 1907 a much-simplified system was initially used. The City & South London Railway (1890), Central London (1900) and Baker Street & Waterloo (1906) all charged a flat fare at the start. While tickets were issued from ticket offices, they were collected or cancelled before proceeding to the platforms, and on the City & South London Railway turnstiles ensured that passengers proceeded along

Examples of three early Underground tickets. The first two are point-to-point types where every combination of possible journeys had its own ticket. The one on the right is a scheme ticket where one ticket served for all journeys from stations at the same fare. In some cases the tickets were very difficult to read and the station list might actually continue on the back.

the approved one-way route to the platforms. On the first two railways this arrangement lasted a few years, but on the Baker Street and Waterloo it was abandoned after a few months. In each of these cases, and where new lines opened, graduated fares were then deployed, requiring the introduction of ticket checking and collection at the end of the journey. Checking at the beginning was continued, in order to prevent access without a valid ticket.

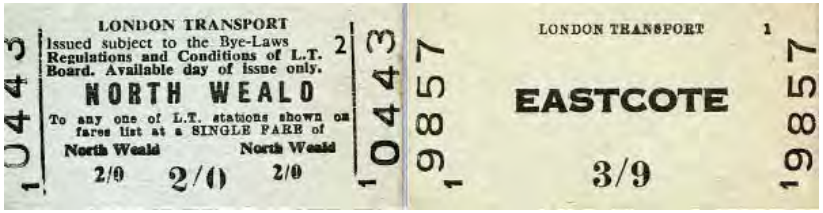
A Huge Range of Ticket Types

The gradual inauguration of through booking facilities between the tube, District and Metropolitan Railways made point-to-point ticket issue increasingly awkward. Traffic on the London underground was steadily increasing—each (usually very small) ticket office had to keep on hand several thousand different ticket stocks and system development threatened to make ticket issuing impracticably slow unless changes were made. Between 1911 and 1927, whilst through booking systems were blossoming, the introduction of the 'scheme' ticket took place. This was a ticket that listed all the stations available to the passenger at a particular fare. This simplification alone significantly reduced the number of tickets that were needed in the ticket offices, since one scheme ticket could do the job of ten or more point-to-point tickets. In the last wave of scheme ticket introduction it proved possible to withdraw about 7000 sets of tickets from the ticket offices. By about 1926, once the scheme ticket system prevailed, a special check of ticket sales took place lasting about three years. As a result, some very little used tickets were withdrawn enabling the total scheme ticket stock to be reduced from about 50,000 to about 20,000 sets. (A passenger wanting to under-take a journey for which there was a quoted fare but not a printed ticket was issued with a handwritten paper ticket—a slow but mercifully infrequent event.)

The scheme ticket prominently displayed the station at which it was purchased, together with the fare paid, but the sometimes large range of destination stations meant the type size had to be rather small. This led quite unexpectedly to the discovery that it was possible for ticket collectors to establish a ticket's validity simply by noting its originating station and fare paid, and rapidly calculating whether or not the passenger had paid enough money for the journey; ticket collectors very rapidly learned the fare due for the majority journeys that ended up at their own station. The stations to which the ticket was available were printed on the face of the ticket (and sometimes the back as well) largely for the benefit of the passenger and was a final arbiter in cases of dispute.

The advantage of the scheme ticket was that it allowed a better concentration and distribution of tickets in the ticket office, which greatly speeded up ticket issuing, eased accounting processes and improved ticket stock control. From the passenger's point of view it eased congestion at the ticket office window and introduced an element of freedom as to which route could be used. Unfortunately, in the 1920s and 1930s statutory obligations and restrictive agreements meant having to keep point-to-point tickets for bookings to stations of the main line railways, although some individual concessions were granted (such as to Wimbledon and Richmond line stations on the Southern Railway and from Wood Lane to Ealing on the Great Western). Some of these restrictions still leave traces today, for example most stations actually served by Underground trains are regarded as being wholly within the Underground's overall ticket system, while main line stations available only by changing trains might or might not be.

After the Second World War, virtually all scheme tickets were replaced by a new type of ticket called a 'Station-of-Origin' Ticket (SOO ticket).



These are examples of station-of-origin tickets used on London Transport railways in the 1950s and 60s (the later one on the right eliminating all but essential information). Ticket collectors were expected to learn what the fares were.

These tickets bore the very minimum of information and were the ultimate acknowledgement that a good ticket collector did not need to be troubled by the clutter of listing destination stations, and the space freed up allowed even more prominence to be given to the originating station and the fare paid. SOO tickets were available for a journey to any Underground station from the station at which purchased to the value of the fare shown on that ticket. Some British Railways stations tolerated London Transport issued SOO tickets.

All the tickets mentioned so far were the standard 'Edmondson' size and were generically known as ticket office 'card' stock. Latterly these were all coloured green but in earlier years other colours had been used.

The Passimeter System

Mainly in an attempt to reduce staffing costs a concept that became known as a 'passimeter' was tried, and had limited success. The original 'Passimeter' at Kilburn Park in 1921 was a free-standing ticket office kiosk in an arrangement that required all passengers entering the station to file past a ticket office window. Here their ticket would be issued and cancelled by the booking clerk in one operation (or simply checked if they already had one), avoiding the need for separate ticket collectors to check way-in tickets (except in the rush hour). At quiet times, outward passengers also filed past the one of the two ticket windows and the booking clerk (rather than the ticket collector) was responsible for collecting or otherwise scrutinizing the tickets. The arrangement allowed useful staff reductions to be made and was deemed a great success, though enforcement was encouraged by means of turnstiles which could be released (or not) by the clerk—presumably this was the origin of the name. A number of 'Passimeter' installations followed, and this system gave rise to the familiar wooden ticket booth which took on board the name, although the majority of later installations lacked any mechanical passenger control (and nor did the clerk check tickets)—they were in truth merely free standing booths.

This shows a typical station arrangement. In the centre is a pair of 'passimeter' ticket booths, each with ticket issuing windows each side (the one on the left closed). To the left is the ticket collector's position, in parallel with the passimeter. At the near ends are further windows used only for selling season tickets when traffic was heavy.

Chapter 2
Early Moves Towards Automation

Ticket issuing had been speeded up only slightly by the judicious management of ticket stocks and improved ticket office layouts, but this alone barely compensated for the extension of through booking facilities and the need for greater stocks of tickets caused by extensions to the Underground.

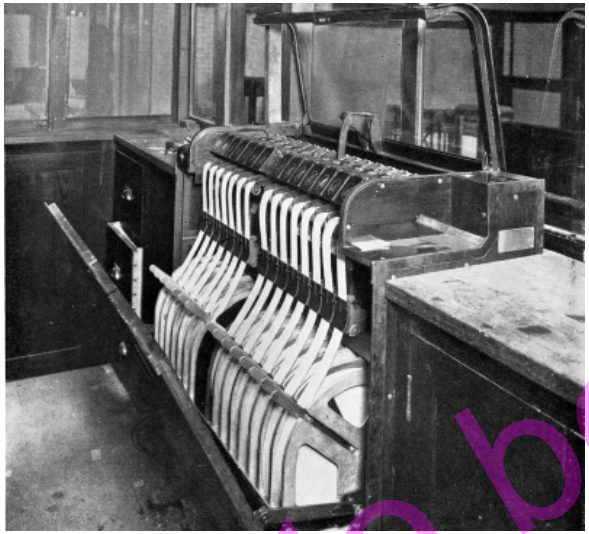
To improve efficiency, some booking office mechanization was inevitable. In 1922 a mechanical ticket machine, known as a 'Rolltic' machine, was first introduced. Each separate 'Rolltic' device consisted of a bank of three or four printing units that could deliver tickets through a common chute to the counter directly in front of the passenger (so the clerk did not have to touch it). Often two or more machines were installed. To issue a ticket, all the clerk had to do was to turn the handle on the appropriate issuing unit. Each bank had only a single issuing slot at the bottom where the actual dating and cutting took place. The tickets were pre-printed and joined in a continuous strip wound on small rolls. About 1000 tickets per hour could be issued in this way and ten years later there were 95 machines in service.

Clerk at Passimeter window, to right of which are banked four Rolltic machines. The clerk is issuing ticket from lower one. A single turn of handle produces and dates ticket and cuts it from roll ready for issue. Also visible are large numbers of less heavily used tickets in racks.

This shows the first machine of this type at Leicester Square in April 1921, employed only at busy times. The later installations were slightly different, but this gives a good impression.

Almost at the same time as the Rolltic machines entered service came the 'Automaticket' machines, introduced in 1921 (similar ones are were commonly found in cinemas). These were motorized, key operated devices, which, for the selected denomination, could issue up to six tickets at a time through slots in a change plate mounted in the counter facing the passenger. Each ticket unit

The Automaticket machine is in front of clerk, tickets stored beneath. Pressing a key causes one or more corresponding tickets to be propelled upwards through the change plate right in front of the passenger, who detaches them before going on their way. A Brandt change dispenser is seen on right.



On far left is shown a ticket window with a rapid printer to its right, in the cabinet. Between the printer and the window is the button pad. Just pushing a button caused a ticket of the corresponding value to be shot onto the change plate in front of passenger. At near left is a rapid printer with covers removed. At the bottom are the various rolls of thin blank card and at the top are the banks of 'unit' printers that actually print and date the ticket when called for. The printed ticket is then cut and deposited on conveyor belt at rear, by which means it is delivered to passenger.

had six keys which instructed the equipment how many of that denomination of ticket to issue. Again the tickets were pre-printed. In 1932 there were thirty of these in service.

The real breakthrough came in 1926 with the use of the AEG 'Rapid Printer'. This comprised eight or more separate printing units, each of which printed a particular denomination of ticket on a blank roll of thin card (though at first the machines used on the Underground were of fifteen units). Each ticket roll could issue about a thousand tickets. Once the ticket was printed and guillotined it was shot along a conveyor and ejected onto the counter for the passenger to take. Both the 'paper' rolls and the printing blocks could be changed with ease and the printing units each had a mechanical counter, simplifying the end of day accountancy; this number also appeared on the ticket. The machine was electrically operated and very fast—up to four tickets per second could be printed. By 1932 there were 90 machines in service with 15 more waiting to be installed. At about the same time they were first constructed in this country under licence by Westinghouse Garrard; the earlier ones were built in Berlin.

Whilst other attempts were made to automate the issuing of tickets from ticket offices, the rapid printer became the general workhorse of the ticket

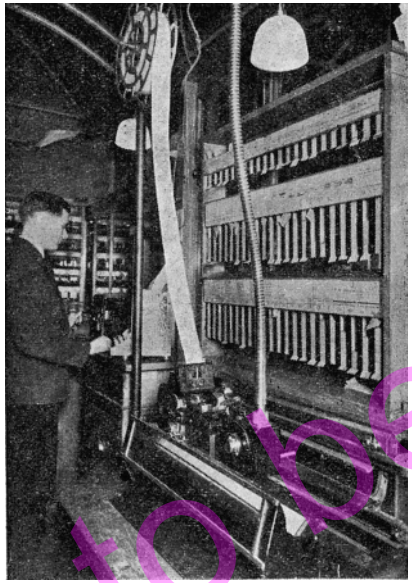
This a post-war mini-printer at LT Museum. This was smaller than a rapid, turned through 90 degrees and lacked the conveyor, the tickets being dropped onto the counter from the slots at the end. The minis used a small push button panel sunk into the counter, just visible here. The later rapids also had these button pads but they were mounted in front of the clerk.

office for many years, only being abandoned when the UTS equipment was introduced in the late 1980s. Furthermore many rapid printers underwent a modification enabling them to encode tickets for modern 'Automatic Ticket Examination'—had this fortuitous design feature of rapid printers not been available there is no doubt that the introduction of ticket gates for the Victoria Line AFC programme would have been hampered.

Another type of machine was the Bell Punch Co's 'Printex' machine which from the passenger's viewpoint was similar to the Automaticket device in that tickets appears through a narrow slot in the change plate. In fact it was quite different in that it could print, as well as issue, six denominations of ticket from blank roll, rather than from zig-zag stacks. of pre-printed stock. Up to six different printing plates were carried on a wheel and the required plate was brought into position when the appropriate key was pressed. All tickets were issued from the same slot. The machine design dated from 1931 and the following year two experimental machines were being tested at St James's Park. Further machines (probably the super-printex variant) were installed from 1936, though production had ceased by 1949 and had not been regarded as very successful.

After the Second World War a smaller and much simpler high-speed machine was introduced, called a mini-printer; this worked on similar lines to the 'rapid' but lacked the belt conveyor, so requiring the clerk to physically move the ticket from the machine to the passenger. The machine was much smaller than the 'rapid' and had only six printing units, but this vastly reduced the cost. There was an urgent need to replace 73 early Rolltic machines dating back to 1922 and 35 machines of the unsatisfactory 'Super-Printex' type (though odd ones were still in use in 1951). A small number of the earliest 'rapids' were also becoming life expired.

After trials at Aldgate East the 'mini' was found highly suitable for use at busy secondary ticket windows, or at the less busy stations, and 100 were ordered in 1949. Card stocks were always required where a 'mini' or 'rapid' was provided, either as back-up stock or for the less commonly used fares. When the 'rapid' wasn't working the clerks had a very hard time. The need to



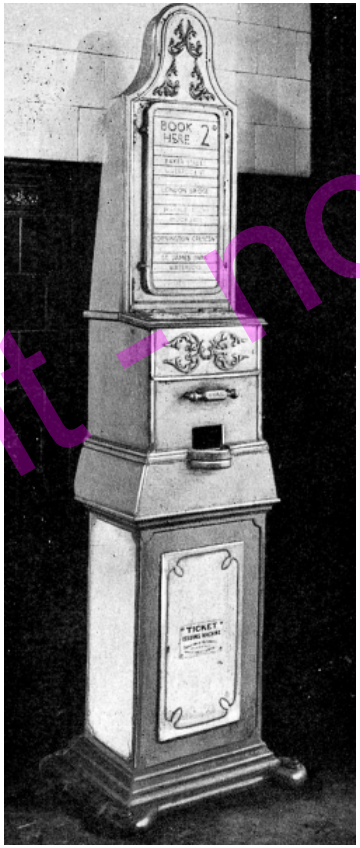
The rather ungainly AEG machine, the ticket roll hung above the moveable carriage. This is reputed to have been tested at West Kensington

retain the pre-printed card stocks naturally complicated accountancy and reduced the scope for space reduction (for example the ticket racks and date press had to be retained near the ticket window).

Another unsuccessful type ought to be mentioned. This was the AEG Ticket Issuing and Printing Machine, first introduced as a hand operated device in 1927. This was designed to print over 100 different ticket types for which there was only a small demand and was operated by selecting the required ticket type by means of a pointer and then operating a lever which moved the operating part to the correct position. In 1928 this rather ungainly means of operation was eased when it was altered to electrical operation. There was only one of these and it was felt that in the environment of the London Underground ticketing system there was only limited scope for its use and it was withdrawn in 1931.

Chapter 3
Early Passenger Operated Machines

Even while attempts were being made to simplify ticket issuing, measures had already been adopted to improve passenger handling at stations by the cautious introduction of passenger-operated ticket machines. The first 'mechanical' machines were provided in 1904 on the Central London Railway. These were of the 'pullbar' type which required passengers to insert the appropriate coin or coins and then pull a handle, which caused the ticket to be issued through a chute. Pullbars were also used by the Metropolitan and District railways to help take pressure off ticket offices; these had a handle at the front of the machine that pulled a ticket from the stack and dropped it into a collection tray. Tickets were of the usual pre-printed card stock type and the machines did not give change. Their use eventually became widespread even though they were slow in operation. They were inexpensive and simple mechanical devices. This could be a problem: it seems that the first specimens lent themselves to fraudulent operation by spurious coins (it was reported that on at least one occasion receipts from several machines at one particular station amounted to half a bucketful of soft iron washers). By 1932 only 43 such machines remained in service on the Underground group of lines. The Metropolitan Railway first used automatic machines in January 1906 and had 30 in service by the end of 1913 (26 selling penny tickets and four at twopence), with a further 17 on order. All were of the 'pullbar' type which cost between £37 and £43 each, depending on coin denomination accepted. The machines were usually fixed near the ticket offices and issued the most popular ticket type.



An example of a pull-bar all-mechanical ticket issuing machine, probably in mid 1920s. This one represents the 2d fare and stations listed include Baker St, Mornington Crescent and St James's Park.

By 1908 further technical developments had been made and an electrically operated machine was introduced within the Underground Group (and later the other railways that joined the Group). At first, these machines issued pre-printed card tickets (like the pull-bar type) but the coin mechanism was more discerning. Detection of the correct money activated the ticket issuing mechanism, so that all the passenger had to do was to insert the money. At the end of the 1920s the old mechanisms were replaced by AEG printing units similar to those used in the rapid printers, which printed, dated and numbered tickets on thin blank card kept on a roll at the bottom. The general appearance of the machine was not altered and the original coin checking mechanisms were retained. In 1932 there were 126 of these in service.

One of the Underground's early electric passenger-operated machines (introduced from 1908).

It was also in the late 1920s that a similar type of printing unit was employed in another type of

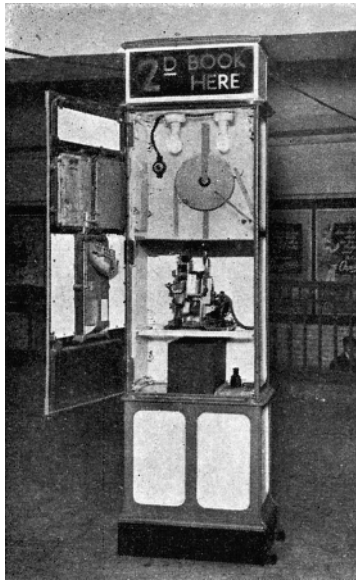
One of the Underground's Pearce electric passenger-operated machines, which briefly gave change.

machine (the 'Pearce' machine), this time in combination with a change giving mechanism. The Pearce machines issued one denomination of ticket between 1d and 5d and gave change if a 6d or 1/- coin were inserted. Unfortunately this early attempt to offer a change giving facility was really challenging with the technology available and was not found robust, having quickly to be withdrawn. Change giving remained a major problem for many more years and was partly addressed by installing a few change giving machines. Around 1930 a Brecknell, Munro & Rogers machine was tested at Oxford Circus which gave change in copper for the five main silver coins but widespead introduction was never pursued.

At many stations individual ticket machines were installed to issue the most popular tickets without recourse to the ticket office, but at larger stations it became the practice to arrange them in banks in an attempt to make them the favoured system for obtaining a ticket. Victoria was an early station to do so and had several banks to ease the pressure at the ticket office. It was reported in August 1923 that a new bank of twelve ticket machines were doing well and that four were issuing at rate of 2½ million tickets a year. Victoria was also the site of a test in 1914 of an electrically-operated ticket machine arranged to issue any of five different tickets by selecting one of five levers provided (the equipment could deal with up to ten, if required). Although this sounded like a good idea it was problematic in practice and passengers found it quicker to deal with single fare machines arranged in banks, which is essentially how things stood until the 1980s.

After 1930 a succession of new types of machine caused rapid progress to be made. The combination of an AEG printing unit with a new type of coin acceptor (called a 'bunch-hopper') allowed passengers to purchase tickets even if they flung all the coins into the machine simultaneously. The alternative 'Hall' machine employed a coin counting (rather than weighing) mechanism and accepted halfpennies. It is worth pointing out here that many fares were under

From the late 1920s, at busy stations where space permitted, the banks were sometimes broken up and machines were installed within the way in passenger flow. This view of Charing Cross shows new AEG bunch hoppers arranged this way and fitted into smart wooden cabinets.



A Hall ticket machine with front opened to show mechanism

sixpence and that pre-decimal bronze coinage, comprising halfpennies and pennies, could be 'counted' by weight as the former weighed half the latter. Threepenny pieces (either silver or brass) were not usually accepted.

The first 'modern' type of machine (in use by 1932) was the BMR machine, made by the British firm of Brecknell, Munro and Rogers. This accepted coins indiscriminately, sorting them and picking them up on revolving wheels where they were counted. Whenever the amount inserted was found to be equal to or greater than the value of the particular ticket value available from that machine then a ticket was automatically issued and any extra coins were 'stored up' until the machine received some more coins to complete what it presumed was a second transaction. For example, in the case of a machine set to issue 2d tickets a passenger might insert 3½d in one go, in which case only one 2d ticket would be issued and the remaining 1½d would be 'stored' until the last ½d (or more) had been inserted, completing a second transaction.

These AEG machines could also be installed in banks recessed into walls, reducing the risk of obstruction. All servicing was done from the front.

The familiar sloping front machines with the illuminated fare panels were first introduced in the summer of 1937, again by the Brecknell concern, and with a mechanism similar in operation to their earlier type of machine. The initial 24 machines first came into use at Leicester Square, soon followed by another 27 at Piccadilly Circus; each machine was regarded as being able to issue tickets (with change) at the rate of 25 a minute. The use of these machines spread very rapidly and by about 1960 there were over 750 in service, with all the earlier devices superseded. In the mid-1960s a modernized version of this long-lived design was introduced (similar in shape but painted silver instead of blue). The mechanism required a 50 volt rather than a

A 1937 poster introducing the new sloping front BMR ticket and change machine

New station at Northfields with free standing AEG machines in modern cases given prominence over ticket office.

240 volt supply, which was now felt to be safer in public areas, the colour indicating the voltage used within.

LT thought that the sloping front machines should be seen as the main means of ticket purchase and arranged them in banks in prominent positions where they appeared the obvious means of ticket purchase. For those who knew their fare, they were extremely quick to use. Ticket halls designed in the 1930s and later were specifically promoted the use of the automatic machines and the ticket offices (which were still necessary) were reduced in size and either located in a flank wall or, where possible, between the machines and the ticket barriers so passengers were encouraged to use the machines.

A story in the staff magazine for 1951 gives some idea of the scale of ticket issuing then. 64 per cent of tickets were issued by booking clerks using automatic printing machines. 21 per cent of passengers purchased through the 750 automatic machines in booking halls. All machines printed onto a common stock of blank green ticket card on rolls, each of which was sufficient for about 2000 tickets. A recent fare change was described and involved preparation of

Above left is close up of typical sloping front machine showing that each denomination of coin had its own slot. On right is a clerk servicing a machine. Clerks reloaded paper and emptied coinage as necessary. This was usually done from the front, in full public view, and could be quite awkward when station was very busy. This type of machine survived until around 1990.

These sloping front ticket machines were used in large numbers after World War 2 and could be found until the late 1980s. They could be serviced from front and rear.

On the left is a typical bank of passenger operated ticket machines in 1966. Generally speaking they were free-standing and carefully located at an angle to the flows, maximizing visibility without actually getting in the way. Years of experience perpetuated the practice of machines issuing tickets at only one fare, maximizing speed and simplicity of issue. The most characteristic feature was the back-illuminated panel showing fare in red and stations available at that fare in black, listed alphabetically. Nearly all machines gave change where necessary (they shut down if change ran out and managing change at stations became a bit of a black art).

4000 printing plates and altering the mechanisms of 300 machines and great planning was required.

The balance of 15 per cent of tickets were issued by booking clerks from traditional card stock held in ticket racks. Even this amounted to about 5½ million tickets a month. These were printed by specialist ticket printers who set the type by hand although standard wording was precast onto blocks used for the most common layouts. The tickets were printed individually in special machines on preprinted card at the rate of 12,000 a minute.

This looks simply like a bank of ticket machines but it is the rear wall of the ticket office at Ealing Common. From the other (much wider) end the ticket office looked like an ordinary ticket booth. The main ticket window was along the other long edge (out of view here). This device was not quite ready when the new station building opened and a temporary office was installed for a few months (also roughly triangular in plan and including ticket machines).

Collected tickets went to the ticket sorting office at the rate of 1.5 million a day. From observing where tickets were collected, the journeys actually made by passengers could be established periodically; this was not otherwise easy with tickets available anywhere within a price range. After any necessary inspection at the sorting office the tickets were recycled.

Two particular branchline developments of are worth mentioning here, just to prove that no idea is entirely new. First, at the newly reconstructed Ealing Common Station in 1931 a triangular section booking office was installed. This was arranged so that one apex of the office pointed towards the station entrance in a way that rendered two of the three faces visible to passengers entering the station. Along one face the usual ticket office windows were provided and along the other a bank of automatic machines. This allowed passengers to form into two distinct streams for their ticket purchases, and because the machines were built into the ticket office they could be serviced from within, making servicing easier and more secure. These advantages were subsequently claimed to be novel over 30 years later when the 'multi-fare' machine was installed at Hammersmith.

The second branch-line development was an attempt to mechanize the 'Passimeter' system, described earlier. The improvement was to employ coin-in-the-slot technology. This took the form of extended trials at, amongst other places, Earls Court and Westminster. In parallel with the normal Passimeter arrangements, electric slot machines were provided. Upon inserting the requisite coins, the passenger would receive a ticket (and if necessary change) and a mechanically-locked turnstile would be released to allow entry to the platforms. This was probably the first ever example of automatic ticket gating on the Underground, but like some later schemes the feature was not long lived. The Underground company spokesman said: 'the London public seems to dislike turnstiles, and it is unlikely that they will be adopted to any extent unless a simple flat fare system similar to New York is introduced'. That was in 1932. Forty years later that issue was still being debated!

Some useful information was published in 1928 which set out some of the background to the ticketing system and what it cost. At that time a million

This shows the ticket machine with automatic gate at Westminster station in late 1920s. This is arguably the first automatic gate on the Underground. The tripod type gate was disliked and equipment was out of use by 1932.

The arrangement of ticket machines at Bank in 1928 shows flows optimized to use them. The six machines are arranged in groups from 1d on left to 6d on right; one machine faces front but there are two more, back to back, behind it. Change (and information) could be obtained from the man at the kiosk. The Underground was sufficiently proud of this automation to erect this huge sign (it has been retouched on the image because flash has bleached out some letters, but other photos show it to be real enough)

passengers a day used the system and it was considered that the cost of the fare collection system was about £200,000 annually, of which about 80 per cent represented staff. There were over 500 booking clerks who, alone, accounted for half that cost. In addition were the ticket collecting staff, ticket sorters, traffic audit staff, ticket ordering staff, and then the cost of stationery and printing. Booking office costs represented six per cent of the whole of the Underground's expenses, supporting the drive to introduce automatic machines.

In terms of speed, it was possible for booking clerks to work astonishingly quickly and when most people wanted basic tickets (for example at times when workmen's tickets were available) tests suggested clerks could issue well over a thousand tickets and hour. Analysis of transactions indicate some variability in requirements for change, but 45-55% might be typical. Of those needing change half tendered a sixpence and the rest a larger coin. Great effort was made to facilitate speedy booking by optimizing the arrangement of equipment inside the ticket office. The need to give change slowed things down as passengers often fumbled to collect their money and a new design of change plate was introduced with an upturned end on the passenger side allowing the money to be scooped off with ease. It is doubtful whether the automatic machines were faster than a good booking clerk but their increasing number eventually made them the preferred means of ticket purchase.

Chapter 4
Need For Automatic Gating Trials

The need for more automation

Once the post war demobbing of the armed forces had ceased, London Transport found it more difficult than ever to recruit suitable staff to work in the railway or bus operating departments. The situation eventually became so bad that by the late 'fifties they had resorted to opening recruitment offices overseas. The intention was to entice people from the diminishing British Empire to come to the UK, encouraging them to come to London and work for London Transport with promises of free air fares and hopes of an improved lifestyle. This exercise, though costly, helped maintain staff numbers to some extent. Nevertheless, for many years between the 1950s and 1970s, London Transport was not able to achieve its full complement of staff, although some years have been very much worse than others. One effect of this was difficulty in maintaining a complete ticket office service and another was a reduced staff to check tickets properly.

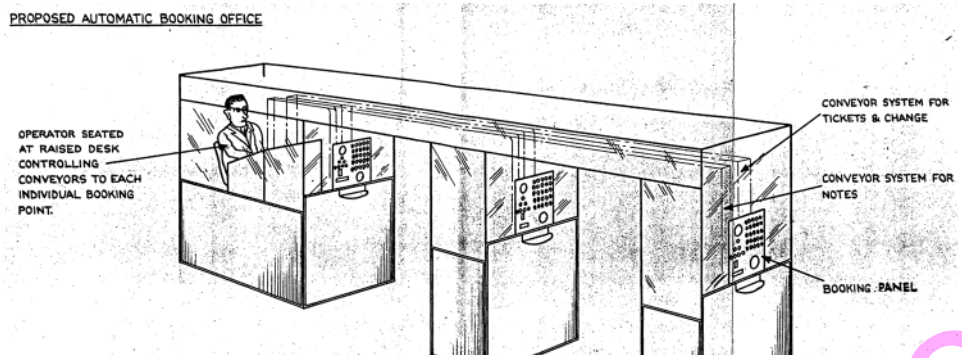
It is against this background of staffing difficulties that the detailed planning of the Victoria Line took place. London Transport now found itself in the slightly awkward position of being committed to a new railway which it recognized it would have great difficulty staffing: with the eyes of the world upon it the question arose how to operate the new line with fewer staff than on the traditional system and the answer seemed to lie with using new technology.

In the summer of 1962 Anthony Bull (LT Board Member) visited North America and looked at the emerging systems being developed to issue and check tickets automatically. One of the larger installations proposed was for the Bay Area Rapid Transit System (BART), being built in California; the ticket control proposals were being put together by a company called Advanced Data Systems (ADS) who were prevailed upon to send a copy of their proposals to Bull, in case this suggested whether a similar system might work in London. Bull explained to colleagues that there were several American firms looking at Automatic Fare Collection systems but ADS appeared to be ahead of the game. Bull had explained to ADS that (unlike BART) London was an old system with a complex system of fares and that it might be helpful if ADS visited to make a preliminary study. For their part, ADS considered that they understood the need for efficient ticket barrier design and ticket issuing equipment (both with high reliability) and felt that a stored fare system would simplify some of the complexity.

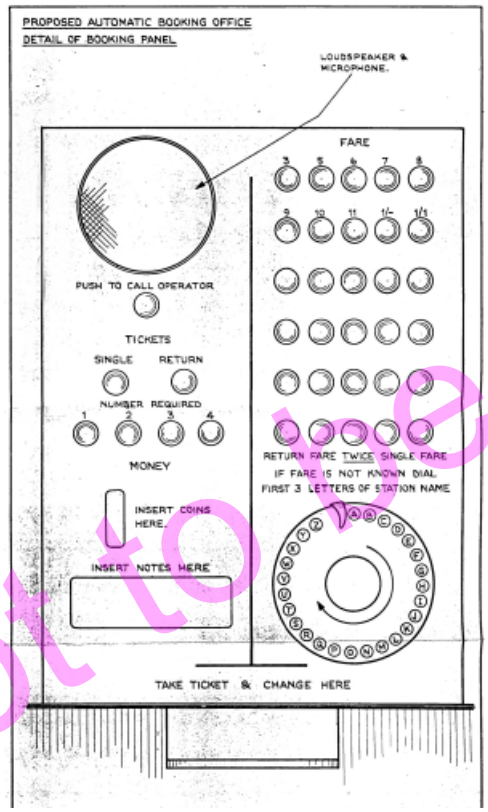
ADS was not discouraged when LT sent them plans of five representative stations to show them the challenge, nor when this was followed up with details of the ticket system that explained that in addition to 'simple' tickets there were those confined to times of day, days of week, lengths of time for nearly any period up to a year, at the passenger's whim, with extensive interworking with BR and with formidable arrangements for intermediate availability or dual availability of route. Indeed the ADS response suggested that none of this was insurmountable and they wondered if, were they to become involved, they could have a go at computerizing the staff payroll system (at that time still all done manually)!

ADS then sent a copy of their report into gating the Long Island Railroad (which led to an experimental installation of gating at two stations in 1964, these being the first railroad automatic gates in the USA). At this point Bull began to involve the Underground's signal engineer, Robert Dell, who amongst his other responsibilities was responsible for purchasing and maintaining the Undergrounds passenger- and staff-operated ticket machines. The ADS visit was arranged for early 1963 on the basis they would send two people, but already it was clear that installing anything systemwide would be the only way to achieve the benefits of much lower staffing. It would, though, be very expensive and there were doubts about whether it could cope with the through BR tickets and existing passenger expectations or whether it was even possible to install the equipment at many stations because of the space required. The

ADS response was that there were only a few stations where there were severe space problems and thought there were alternative solutions (one of which was to install ticket readers on escalators, if necessary moving with the escalator). ADS was told that LT had created a study group to look specifically at the traffic aspects of AFC. Significantly, by the time ADS actually appeared in London, Dell had already studied the problem himself and had begun to make his own suggestions about how technology might be deployed.



A signal department drawing from 1962 showing a tentative design of how an automated ticket office might look. At this stage, no gates are included. Method of operation is not entirely clear but it seems as though anything complicated would involve the attendant (who supervised at least three sales points) with cash transferred via conveyors. This was a system used in some shops but was falling out of favour and would have been excruciatingly slow.



This is a close up of a drawing of one of the speculative sales points.

In March 1963 LT disclosed to the press that it was examining the case for an automatic fare collection system which would be tested at one or two stations. If a system proved feasible it would be used on the recently-authorized Victoria Line; this was expected to open in 1968 so it would be necessary to develop a reliable electronic system very quickly if this target were to be met. Following their visit the ADS report emerged in April 1963.

A more detailed review of the ADS report is given in Appendix 1, but to summarize the position here the report basically suggested that an AFC system in London was entirely feasible notwithstanding the great complexity of the network, though later evidence suggested that ADS might still not have understood just how complicated the ticketing system actually was.

Whether the ADS report told LT anything it didn't already know about its congested stations, its complicated ticketing system or the high cost of revenue collection is very doubtful. Much if this had been known thirty years earlier. Whether LT had not already worked out that changing from one system to another would be extremely challenging, costly and disruptive is doubtful based on the comments senior officers had made in 1962. The value of the ADS report is in giving credence to the likelihood that a suitable technical solution was plausible and that in the US such systems were about to be installed and that it was probable that by some adaptation similar technology might work in London. The immediate problem was that there was not a fully functioning system in use that London could look at (an experimental system was installed at two stations on Long Island in 1964 and a full AFC system on the Illinois Central Railroad was installed during 1965 and eventually the BART system in San Fransisco in 1972).

The ADS report observed that so long as non-automated tickets were available on the Underground it would be impossible to arrange either stations or the ticket system optimally. For this reason, ADS proposed an interim automatic system that could be introduced progressively and when this had

been completed it would be possible to withdraw manual ticket checking altogether and convert to a long-term technology. For this, the ideal would be a stored-value system where travel units purchased in advance would be used to fund a number of individual journeys. For this, the technology required provision for every ticket to be coded and for the code to be read and rewritten at each exit gate with the fare computation carried out extremely quickly.

Whether ADS grasped the impossibility of this happening any time soon in the context of London Transport's financial position is hard to say, but the more important factor was that an interim automatic system, which could be deployed on the Victoria Line (and perhaps elsewhere), was thought entirely feasible from a technical and operational point of view. A full summary of the ADS report is given in Appendix 1, where it will be seen that some factors were taken forward, some were not, and some technical features were developed in a different way by LT.

The Victoria Line was finally authorized in August 1962, and with a proposed construction time of just five years there was mounting urgency to determine whether to attempt an automatic revenue control system as it affected the design of the ticket halls. The feeling was that, whilst acknowledging tremendous difficulties, a system not unlike that in Illinois would be feasible in London and ADS was employed to assist in its development. In fact both ADS and Dell learnt a lot from each other whilst experimental schemes were being considered and some of London Transport's ideas were used in Illinois before London had its own system.

The Chief Signal Engineer at this time was Robert Dell, and his various responsibilities included ticket machines. In the field of signal engineering he had already pioneered the centralization of signalling and introduction of completely automated control of junctions and had found ways to employ the latest technology in order to reduce staff numbers. He now began considering ways of automating trains (to reduce staff) and naturally began to consider how station operations could be automated to achieve staff reductions. Amongst the various ideas were included station control rooms supervising stations using CCTV and automating the whole process of ticket issuing and checking.

Apart from anything else, Dell believed these jobs were labour intensive, unreliable and to a large extent exceptionally boring for staff. Ticket collection was felt particularly tedious and consequently the job was not done well and passengers were allowed to get away with a large amount of fare evasion. Staff fraud was also suspected, mainly in the process of 'excessing' passengers without tickets. The staff shortages meant that ticketless travel was not only condoned but sometimes necessary; when passengers went to pay at the arrival end of the journey (if they did) then the money was very difficult to account for.

Dell could see no reason why a machine should not be capable of checking a ticket for validity—this was in principle a very easy thing for a machine to do but very difficult for a human to do accurately and consistently, especially when presented with tickets at the rate of upwards of 40 a minute, even assuming that the collector was both keen and good at his job. It is possible this assessment was only partly correct as some ticket examiners were capable of astonishingly accurate examination whilst huge difficulty was found in getting the electronic equipment to operate to a satisfactory degree of reliability.

Chapter 5
Initial Ticket Handling Trials

The need for equipment development

ADS drew attention to the fact that while some technology existed to support ARC, there were gaps that needed filling and some equipment that would be better designed specifically to meet London's needs. Specifically, satisfactory and fully tested designs were needed for:

- Automatic gates (needed at system entry and exit);
- An automatic ticket reader;
- A fares computer

Automatic gates had to be constructed to maximize passenger flow, provide adequate resistance to misuse and people without tickets and take up the minimum of space consistent with housing the ticket reader and gate operating equipment. Tripod designs had not entirely been ruled out but LT considered (correctly as it later turned out) there would be some resistance to them so a design with some kind of self-powered barriers seemed necessary.

An automatic ticket reader was clearly essential and there was nothing suitable already available. A reader essentially needed to comprise two elements. First there was a transport mechanism (the transporter) into which the passenger inserted the ticket and out of which the ticket, once read, would either be returned to the passenger or diverted into a capture bin. The most crucial aspect of this was reliability. A challenge was that with the existing ticket system there were two thicknesses of card used depending on whether a ticket was issued by an automatic machine or manually from a ticket rack. There were then season tickets of a completely different size. These important features needed to be taken into account before any form of transporter could be designed and raised all kinds of issues. The second job of the ticket reader was to read the code on the ticket whilst it passed through the transporter. This required early decisions about the form in which the codes might take and the medium by which they would be carried on the ticket. Magnetic ink was apparently already a known art but had serious restrictions. A magnetically susceptible medium on the back of the ticket was the suggested ideal, but this would need developing as it was not felt there was anything suitable available. This meant more development work in parallel with designing and testing a transport mechanism.

ADS was very keen to use magnetic drum technology as a storage medium for the station equipment. However this did not deal with the question about the form of logic circuit that would be required to compare the ticket code with the various data that would be stored at stations to test ticket validity. Since the use of programmable computers was quite inconceivable at that time, a station 'comparator' would have to be devised. The detailed design of this would depend heavily on what information had to be coded on the ticket and how this would be coded. LT could only guess at this at the start, and had to devise a coding system very quickly that would be reasonably future-proof even though at that stage some detail could only be guessed at. The coding might also be influenced by the choice of a magnetic ink or a magnetizable backing system, which was not then clear (an optical system appears also to have been contemplated).

Early development work

The first practical moves came towards the end of 1962. Some early contemporary sources soon came to call the idea 'Magic Eye' ticket checking, though it is now difficult to tell if this had official currency.

The name 'Magic Eye' ticket checking implies a possibility of an optical check on information coded in some way onto a ticket. No doubt LT performed numerous rough and ready experiments to see what was and what was not feasible. Having come up with a few ideas that appeared practicable, there then came the essential task of seeing what the public made of it; a ticket that operated perfectly in the laboratory might not work so well after being

subjected to the extraordinary things passengers did to tickets whilst in their possession.

This initial 'survival' test was instituted towards the end of March 1963. The printing block for rapid printer 9d tickets at one of the ticket office windows at Earls Court (A) office was exchanged for a new block that included a code. The usual printed information was retained, with the code printed towards the top right hand side and taking up most of the upper third of the face of the ticket. It consisted of a series of almost square markings arranged in three rows. Normal green ticket machine paper was employed, but what sort of ink was used is not now known. After use, the tickets were sorted out by the revenue office and subjected to an 'electronic check' to see how the code had withstood handling. This is believed to have been an optical check by photo-electric cells, and it is therefore unlikely a magnetic ink was used.

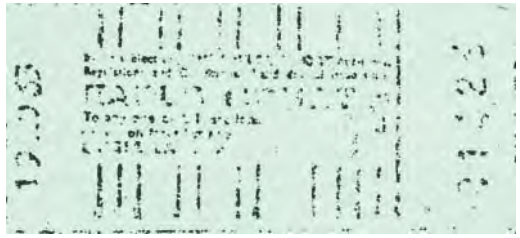
This represents the three types of test tickets used in 1963 to investigate the durability of the coding. In each case the top track appears to be a reference or 'clock' track. Lines 2 and 3 appear to be separate binary tracks. Track 3, when decoded, appears to correlate with the fare paid (in pennies). In that case line 2 would be station (this decodes to 61 which is approximately correct for Earls Court, which was later allocated 63). The poor quality of two of the images regrettable (they have had to be recovered from very poor photocopies).

The coding seems to be a form of binary, with the series of 'squares' in the top row forming a reference track.

Although trials continued on this particular 9d ticket stock, towards the end of 1963 the 'square' code format was altered to a 'bar' code format, with the arrangement of code bars similar to the earlier 'squares'. This time the ink was almost certainly magnetic. At roughly the same time tickets at additional fares (notably 3d, 6d and 1/-) were also issued with the bar type codes but in these instances the lower row of code bars was printed along the bottom edge of the ticket (with the top two rows of bars staying in the same place).

The final development was supposedly introduced from Thursday 21st November 1963 but the tickets were noted on issue earlier in the week. In this case the three rows of short code bars were replaced by two rows of rather longer bars, one along the top edge of the ticket and one along the bottom. In combination, the code bars formed a ternary code system (ie a system of numbers to base three, in contrast to binary, which is to base two). There were 15 code positions reading from right to left as opposed to the double set of 10 code positions of the earlier tickets. Magnetic ink on green card was used, and tickets issued from Numbers 1 and 2 rapid printers (again at the Earls Court (A) office) at 3d, 6d, 9d, 1/ , 1/6 and 1/10 fares. This last code arrangement appears to be very much more robust than the earlier, tiny markings which may have proved inadequate. The 2 track ternary code set the pace for the immediate future.

Represented here is the final version of the Earls Court pre-gate trial tickets, once more issued from a 9d rapid printer. So far as can be established this is the very first design to adopt the ternary code using 'bars' set out along each edge.



Chapter 6
Early Field Trials

The next stage was to move from ticket handling (or survival) trials to the testing of automated ticket reading on site, using a real automatic gate (which would reveal new challenges to the engineers). The initial experiment focused on 'Way In' ticket checking, so there was not much opportunity for tickets to be subjected to the normal rigours of use in the few yards from the ticket office where they were issued.

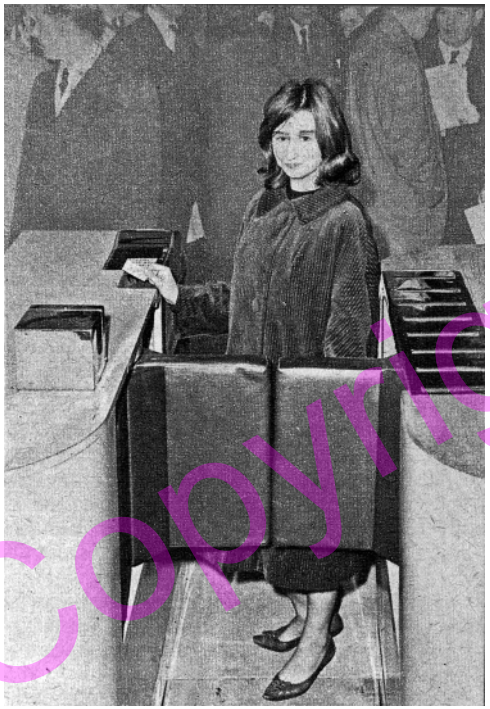
Stamford Brook

The first experimental installation was made at Stamford Brook early in 1964 with equipment of London Transport's own design. The existing manual ticket barrier remained in use for all 'exit' passengers and 'inwards' seasons, while an 'inwards' automatic ticket gate was erected close by, being commissioned on Sunday 5th January. This was prominently marked 'EXPERIMENTAL TICKET GATE' and the normal barrier received an equally prominent sign marked 'SEASON TICKETS WAY IN'. The new automatic gate consisted of two box frames between which the passenger passed. The left hand wall, slightly higher than waist height, had rollers along the top for passengers to push their light hand luggage along. The right hand wall had a slot at the front for the ticket to go in, and a second slot at the top for the ticket to make its reappearance. The physical gate consisted of a metal frame filled with foam-rubber and covered in 'leather', but the bottom of the barrier was sufficiently far from the ground to allow heavy luggage to be pushed underneath.

The first of the AFC ticket gates, at Stamford Brook, had a home made look. The small illuminated sign to the right reads 'Stop' or 'Go', the latter illuminated if a correct ticket is inserted. Just visible in front of passenger is one of the two gate paddles which the passenger pushed through, once correct ticket unlocked the mechanism.

At slightly reduced size are examples of the Turnham Green tickets, the colour yellow being used for tickets intended to work gates. The coding on all tickets was the same and the thin card the same whether machine or manually issued. On the left is a manually issued ticket that has visited a date press. The second one appears to have come from a rapid printer. The third is a child return (dated by hand on rear); it is intended to be torn in half at end of forward journey (on returning it would not go via the gate). The fourth one (also a 'rapid') shows the change of ink made from August 1964 to improve its magnetic quality.

The method of operation was as follows. The passenger was issued with a yellow coloured ticket (the normal ticket colours being green or pink) and was directed to the experimental gate by a sign (YELLOW TICKETS HERE). The ticket was inserted into the slot, the code was checked and the ticket returned. If it was deemed valid then a 'GO' sign illuminated and the gate was released to let the passenger through. If the ticket was not valid then a 'STOP' sign would light and the gate would remain locked. In practice only a very rudimentary code marking was given to the tickets and was equivalent to the ternary code 80 (understood to be the station number for Stamford Brook, though when AFC was rolled out this station was 222). The tickets were of the ordinary single or return type (Adult and Child). The (visible) code markings comprised two rows of 'bar' shaped marks along each edge made in magnetic ink. The actual code was unimportant since the equipment was provided largely to test the barrier itself, to see whether or not a code could be read with any degree of accuracy and also to test passenger reaction.



The left hand photo shows a passenger about to pass through the gate. The arrangement required the passenger to wait for the GO sign which showed the mechanism had unlocked and then push forward into the 'leather'-covered paddles which rotated into the balustrades, a fresh panel appearing behind the passenger in a manner similar to a turnstile (there were three paddles mounted on a rotating column on each side, accounting for the very large casing). The right hand photo shows a ticket being inserted into the gate. The upper label shows where the ticket would be returned.

Chiswick Park

On Sunday 15th March 1964 a second experimental automatic gate entered service—this was installed at Chiswick Park. The barrier was of a quite different design to the one at Stamford Brook although it obviously shared some common features. Again it was situated in parallel with the manual barrier and dealt only with inwards passengers holding yellow single or return tickets coded with the special ink. It comprised two steel box 'walls' with the right hand wall containing the reading equipment. Between the walls were two sets of gates, one behind the other and with enough room for a person in between.

Chiswick Park (Way In) with the second type of gate. The sign at top to the right is green and says 'Other Tickets' indicating that non yellow tickets had to be presented at the manned barrier. The second photo shows the exit side of gate with ticket being retrieved from exit slot.

Each gate consisted of two doors that could be retracted into their respective barrier wall. This type of equipment was known as a 4-door barrier and it operated as follows. A valid ticket opened the first pair of doors and allowed the passenger to enter the centre section. This done, the first pair of doors closed and the second pair opened to let the passenger continue on his way. This action was extremely fast and in practice the passenger's progress was not impeded at all. A further refinement was that the equipment could retain information from up to three tickets and hence a continuous stream of people could use the gate, there being no necessity to wait for one passenger to leave the barrier before the next one entered. The doors themselves were quite deep and no luggage rollers were provided. The mode of operation of the doors could easily be altered by minor changes to the wiring.

The tickets were issued from both the ticket-office rapid printer and from card stock, although the latter was printed on ticket machine type paper. Most

Ticket at left (a child's ticket) issued from ticket office on the day the experiment started and is hand dated, although it looks as though it came from a rapid printer. At right is a machine issue, probably from a rapid printer. Later examples are known using the brown ink as at Stamford Brook). The code does not include date but does include station of issue and the fare in pence (the child ticket code equals 2d but as the system evolved, later types coded the adult equivalent fare.

fare values were catered for. The tickets were similar to those at Stamford Brook but the code along the edge was more complex. The code was in ternary form and all coded ticket issues were on Yellow card.

Ravenscourt Park

On Sunday 12th April of the same year (1964) a third Way In automatic barrier was introduced, this time at Ravenscourt Park. It was again installed in parallel with the manned barrier and whilst having some similarity with the previous two experimental gates it differed in its mode of operation. This gate consisted of the usual pair of barrier 'walls' with the ticket reading equipment in the right hand wall. However, doors were dispensed with and a 'tripod' type of gate mechanism was employed instead. The gate arrangement was normally locked with a horizontal bar preventing passengers from proceeding. A valid ticket would release the lock and allow the arrangement to turn so as to allow just one passenger through. No indication was provided to show whether or not the gate had released after a ticket was inserted.

Stamford Brook (inwards) was the only experimental station to be fitted with a tripod barrier.

Ticket at left is from day experiment started and is a machine issue (probably rapid printer). The one on the right follows revision of printing plate and the new ink.

The coding initially employed at Ravenscourt Park was 2-track ternary as at Chiswick Park, but following problems with ticket recognition, two changes were implemented from 13th August 1964. Firstly a modified printing plate was provided (with a different coding) and secondly a new formula was used for the magnetic ink which now appeared light brown in colour as opposed to the former black ink. The initial plate was for tickets at the 6d fare, which covered Chiswick Park, The plate seems to have been produced in rather a hurry as the station name and wording was much smaller than usual and there was a typographical error—however it was pressed into service immediately to avoid waiting for the new plate to arrive—LT helpfully pointed out to staff that the ticket's illegibility not a major drawback because it was readily distinguishable because of the brown print! Modifications of a similar type were subsequently made at Chiswick Park.

This shows the ticket entry and exit slots on the Ravenscourt Park gate.

At Stamford Brook and Ravenscourt Park (and almost certainly Chiswick Park as well) coded return tickets at certain fares were issued. The coding was exactly the same as for a single ticket of the same fare value, which is curious considering its reduced availability and the fact that no coded indication was given that it was a return ticket. The same sort of thing applied to the children's tickets (at least at Ravenscourt Park) where again the fare actually paid was encoded with no indication that it was a child's ticket and therefore had a wider availability. In practice, at this stage of the experimental work, the coding on the tickets was largely irrelevant as no 'exit' gates were ever provided which could read tickets coded in the ternary, magnetic ink system. The printing format of the return tickets was horizontal, unlike the usual vertical format return tickets of the period; the printing type was very small because of the reduced printing area caused by the provision of the code. A broken 'tear' line was provided down the ticket where the 'forward' and 'return' halves were intended to be separated by the passenger—after being put through the entry gate at the station of purchase, of course. The code (or rather, part code) on the return half was not needed for the return journey since coded return tickets were not at this stage issued to other stations with automatic gates. The system of tearing return tickets in half was open to question in the face of impending automatic ticket checking and would have to be changed. Except at Stamford Brook these stations all used tickets with a 15-bit ternary code.

Chapter 7
Acton Town and Turnham Green trials

After a long pause in development the next step occurred at 07:00 on 17th May 1965 when an experimental 'outward' barrier entered service at Acton Town, working to a design by Advanced Data Systems. The barrier itself was of a '4-door' type of similar design to that at Chiswick Park. The electronics were necessarily much more complicated than for the inwards gates because a simple 'local station' check was not enough. The equipment now had to read the ticket and then work out whether or not the fare paid covered the journey

The experimental exit gate at Acton Town is shown at left, suitably signed, while traditional tickets are inspected manually on the right. Visible here is the new window (on the 'paid' side of barrier line) at which anyone with no ticket or the wrong ticket presented themselves. When the clerk was satisfied correct fare had been paid, an exit pass was issued.

A selection of single-journey tickets issued from a range of stations at the Acton Town fare in order to operate the exit gate there. Although the Acton Town logic system could check dates there was no means of altering the date at the issuing station and provided the correct fare had been calculated they were accepted at any time.

Below are further images of Acton Town exit gate. On left is the approach end and on right the leaving end. Just visible on left balustrade is the slot used to return seasons and spurious tickets, which seems a long way forward

from the station at which the ticket was issued. London Transport was even more ambitious than this, however. Apart from ordinary single tickets from other stations, weekly seasons, coded staff passes, day off-peak returns and children's tickets (single and returns) were also used in the experiment; the equipment had to handle all these.

Return tickets issued at Acton Town for the first time came in two parts—forward portion and return portion. The latter ticket operated (and was retained by) the Acton Town gate on completion of the return journey, whereas the 'forward' ticket was collected manually when the passenger reached his outward journey destination, and did not ordinarily pass through an automatic gate. Posters provided passengers with full information about the new type of return tickets.

There were two basic types of ticket. Those issued by ticket office rapid printers at the Acton Town fare had two ink code tracks, still using the 15-bit ternary code but with some modification; as before this was printed along each long edge of the face of the ticket. On the other hand, ticket office pre-printed 'card stock' tickets (mostly issued from Acton Town itself) were of a new type, about an inch longer than normal, and with the coding on the back. The code appeared in three code tracks, one along each edge and one in the centre; the code used was a form of 'heptal' (ie to a base of seven). The gate electronics obviously had to discriminate between the two code systems, a matter presumably achieved through one appearing on the face and the other on the reverse (though the gate did not carry a 'this way up' label).


Rate £8 16s. 0d.

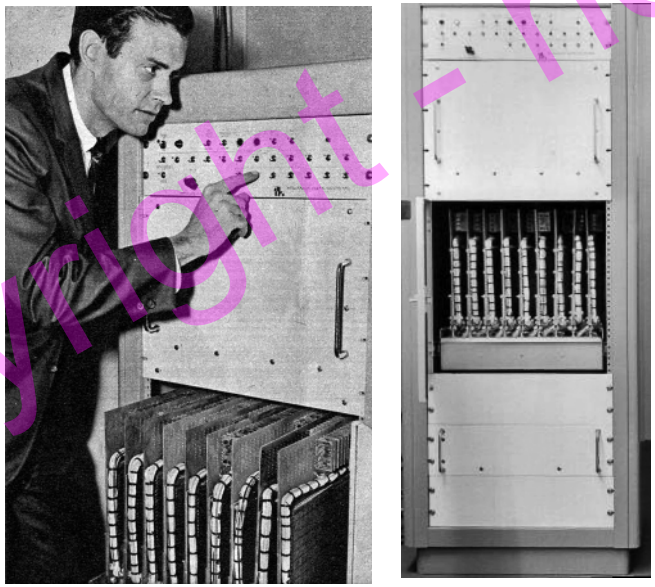
Issued subject to LONDON TRANSPORT By-laws, Regulations and Conditions.
2nd Class Quarterly Season Ticket between
HOUNSLOW WEST and TOTTENHAM COURT ROAD
via Knightsbridge and change Leicester Square
UNTIL
Holder's Name
NOT TRANSFERABLE

An early (yellow) season design for Acton experiment, layout based on ordinary seasons. This was soon changed. This ticket had to operate Acton gate.

Fifteen stations, with high sales of tickets at the Acton Town fare, issued suitably coded tickets from rapid printers. A further five stations participated by selling card stock tickets but not tickets from rapid printers. Thus twenty stations were involved in selling tickets capable of opening the Acton Town automatic gates. As the experiment progressed, this list was varied.

Acton Town itself issued a range of its own encoded tickets where these might be needed to operate the exit gate. This included weekly season tickets. These were the same length as the special card stock tickets but of a yellow plastic material which was more durable than card (but very diffcult to date stamp because the ink would not dry). A range of pre-printed weeklies (with the 3-track code on the back) was available, and the booking clerks stamped them with the usual security overprint number and expiry date upon issue—a special quick drying ink being used with a miniature overprint number stamp.

There was a great deal of hand-wringing about the weekly tickets, superbly printed on yellow plastic material that would have lasted a great deal longer than a week. The need to pre-print these meant that the date validity could not be altered; whilst this was also the case for the daily tickets the risk of misuse (and loss) was much higher for a weekly and the idea of using several rotating stocks was explored so that at least a random element was introduced

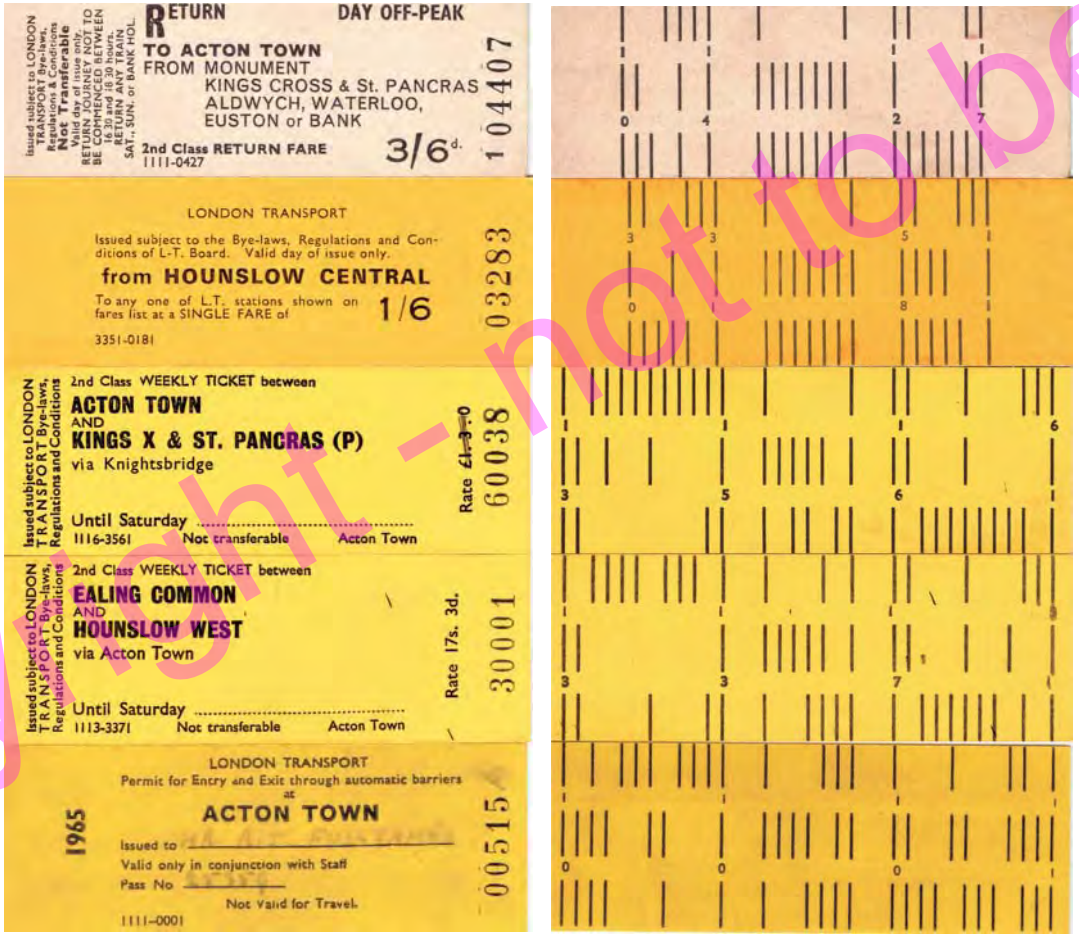


The equipment cabinet containing the electronics that controlled the Acton Town ticket gate. It appears the circuit cards could slide out. This device included a drum memory unit, probably housed in one one the solid-fronted sections.

to discourage misuse. I have not found evidence this was actually done and believe matters were overtaken by events.

The special coded staff passes issued to certain staff working in the Acton area were similar in type to the special weekly tickets— card not being feasible for tickets continually being re-used. Again the passes were yellow in colour. In fact all the coded tickets involved in the Acton Town experiment were yellow except the Day Off-Peak types which retained their customary pink colour. The passes and weekly tickets were returned to passengers after automatic checking, but most of the other tickets were captured by the gate on the basis that the journey had been completed.

For the benefit of those passengers who had tickets faulty tickets, or who had a fare to pay, an extra booking office window was provided on the 'train' side of the barrier to which attention was drawn by a poster reading: 'AUTOMATIC FARE COLLECTION - EXCESS FARES - If you have to pay an excess fare, no matter what ticket you hold, or if you do not hold a ticket at all, please go to the official at the excess fare window..



Images of fronts and rears of the 'heptal' coded tickets either issued at Acton Town or at ticket offices at eight other stations, all designed to operate the new exit gate. At top (pink, but at first yellow) is return portion of an off-peak return. Below is an ordinary ticket from Hounslow Central. There are then two weekly tickets, one with Acton Town as terminal and the other with Acton Town as an intermediate point that had to be recognized. At bottom is a 1965 gate pass issued to someone working nearby (probably signals or Acton Works staff, and station staff). It might be noted the passes and period tickets had extra coding.

When the Acton Town exit gate was installed it appears the Chiswick Park entry gate was rebuilt with a rotary transporter where the ticket was returned via an exit slot immediately above the entry one. Coding was altered to suit the new Acton gate.

At the 'excess' Window the passenger would explain his difficulty to the clerk, who would give him an 'exit' ticket which would let him out through the automatic barrier; the clerk would himself collect any existing ticket held or any fare due. The usual ticket collectors were retained purely to deal with tickets which were not intended to operate the automatic barrier—they did not, at least in theory, now collect any excess fares.

One of the stations that participated in the Acton Town experiment was Chiswick Park, which issued the relevant tickets through a rapid printer. This required altering the ticket plates to reflect the slightly different coding, involving a number of equipment changes. It was probably at the same time that the original entrance gate there was replaced by an improved type with a rotary ticket transporter. Ravenscourt Park and Stamford Brook did not participate in the Acton experiment.

Correspondence in the files indicate that for the Acton experiment several gate-friendly tickets were produced for nearby routes that ought not to have worked the Acton gates; this was deliberate and it was hoped some passengers would attempt to use these so they would be rejected. The outcome has not been discovered.

Turnham Green

The last station to be equipped with a purely experimental installation was Turnham Green. This station received an automatic WAY IN barrier on 27th June 1965 and also a WAY OUT barrier on 25th July 1965; both were designed and built by London Transport. To facilitate the experiment about 50 stations started to issue coded tickets for fare values covering Turnham Green—the coding this time being of the binary two-track type with the coding on the front. This change appears to have been made following intense effort to improve reading reliability by higher quality printing, and new printing blocks in refurbished automatic machines. At the same time the awful truth had dawned that the 15-bit ternary system used at the very maximum capacity could only accommodate about 14 million combinations of code but that vastly more were going to be needed with the suggested method of coding season tickets that was being considered. The new binary coding used 31 code bits, more closely spaced than previously, but with the two end bits used purely to tell the equipment which way round the ticket had been inserted. The 29 'useful' bits allowed more than 500 million code possibilities. The bottom track was purely a reference track (with 31 marks) while the top track carried the actual code marks. Inevitably this meant the coding on the Turnham Green tickets would not work the Acton Town exit gate so tickets at the Acton fare were of the normal green type.

Again, an excess fare window was provided. The Turnham Green, barriers were designed to cope with weekly season tickets of conventional size (unlike the special ones at Acton) and this required an additional ticket slot (provided in the left hand barrier wall) with a separate ticket transporter and associated

This shows Turnham Green with both gates installed (the later, exit, gate is on the left). The two gates were made by London Transport engineers and it might be noted that the size of the barrier arms on the exit gate is smaller.

reading equipment; single and return tickets were handled by equipment in the right hand barrier wall. The layout of the weeklies was very similar to the normal card stock types but two code tracks were provided on the back below the conditions of use; the tickets were also made of yellow plastic. Issues of these stopped on 8th May 1966, although only some of the range of weeklies from Turnham Green had actually been involved in the automatic ticket checking experiment.

Two posters were provided at Turnham Green to encourage passengers to make the experiment successful. One was provided at the Way Out automatic barrier and read:

AUTOMATIC FARE COLLECTION
IS YOUR TICKET YELLOW?

If the ticket which you hold is yellow please use the automatic ticket gate as you leave the station. This is how it works:

1. Put your ticket in the slot, ordinary tickets on the right hand side, seasons on the left of the gate. Valid ordinary tickets will be retained by the machine and the gate will open. Valid seasons will be returned and the gate will open.
2. If the gate does not open or your season ticket is retained please go to the excess fares window. Please lift your luggage, briefcase or umbrella well clear of the gate. The station staff will help you in case of difficulty.

The second poster reads as though a great deal of experience was gained from the previous exit gate experiment—the strange ways of passengers having been identified and assumptions about common sense dismissed! It read as follows:

AUTOMATIC FARE COLLECTION
HOW CAN YOU HELP

1. Please do not crumple, bend or mutilate your ticket. Any disfigurement of the ticket may cause delay because the scanners may not be able to read the code bars.
2. Please do not place more than one ticket at a time in the ticket slot of an automatic gate.
3. Please remove weekly or season tickets from any case or covering before inserting them in the slot of an automatic gate.
4. Please make sure that you use your return ticket in the right way. The new type takes the form of two separate tickets, one

The new inwards gate at Turnham Green in June 1965. This had a second slot, for seasons, in left hand stanchion (and this was the only station ever to have left hand entry slots). The seasons were a larger size and needed a special transporter..

for the forward journey and one for the return journey. It is ESSENTIAL that these are used in the correct order.

Your co-operation will ensure that you are able to pass through an automatic gate without any delay.

We cannot know whether the poster reduced the problems that various passengers might have demonstrated at the various stations with the experimental gates (particularly in regard to point 3!) but clearly the experiments were being closely monitored and every effort made to detect and correct mistakes.

At top are examples of adult and child binary tickets issued at Turnham Green and in second row are platform ticket and exit gate pass, the latter issued at the excess fare window. All these are card stock that have been hand dated. At bottom are examples of tickets valid for leaving station at Turnham Green. The Northfields ticket is machine issued (from a rapid printer) and the Richmond ticket comes from the BR ticket office at Richmond.

It will be seen that while these tests were in hand there were three different technologies in use. First we have the 15-bit ternary system (which appears to have operated with more than one flavour depending on whether tickets worked at Acton Town or not). Then we have the heptal system used at Acton, And now the binary system if the gates at Turnham Green were to be operated. It seems that the design of the 'final' system really began with this binary coding and work must have been in progress for some time as Dell filed a patent application for this system on 3rd June 1964 (the complete specification was filed on 28th May 1965 and patent 1072690 was granted on 21st June 1967). Examination of the patent shows a 31-bit code with 27 useful bits broken into three equal sections, being Station of origin, date and ticket type (or destination station if season). The circuit diagrams suggest that the problem of intermediate availability of seasons had not yet been cracked.

It had been intended to test the Turnham Green gates until September but a report made in August stated that both sets of gates were reading the complete code on ordinary tickets but seasons were being properly read only

This is an example of a Turnham Green weekly ticket of the type inserted into the left hand stanchion of the ticket gates. The tickets were of traditional season ticket size and the layout of the front was standard, except for being on pre-printed yellow plastic. The 31-track binary coding included the Turnham Green station code at right hand end, and Liverpool Street at left, though only the former would be recognized by the Turnham Green gate. Some tickets were coded with Turnham Green in both positions, perhaps to improve reliability.

on the inward gate and the outward gate opened whatever ticket went into the season slot. No explanation was given but it is probably related to the more complex checking that was required which was evidently problematic. Although the experimental equipment was left in service the issuing of coded weekly tickets ceased on 8th May 1966.

Ravenscourt Park still had a viable in gate and some time shortly after the August 1965 project meeting the ticket issuing equipment and gate were altered to the binary system for use at Turnham Green.

General Progress

By this time serious thought was being given to rolling out AFC systemwide. Even by the end of 1964 the costs were high:

Stage 1. Victoria Line gates, structural alterations, ticket & change machines at stations to be served by new line. £1.1 million.

Stage 2. Additional AFC equipment on Victoria Line (mainly gates and note changers). £0.4 million.

Stage 3. In gates at all stations (except those done already). £4.7 million.

Stage 4. Completion of AFC, including 'out' gates at all stations not already done. £2.9 million.

This was an enormous cost and undertaking stages 3 and 4 was regarded as speculative.

Meanwhile doubts were arising about the value of the ADS involvement and while some features of the Acton Town system were quite good, Dell had come to believe that LT was now just as capable of developing the required electronics in house. Even so ADS had by then gained some experience in commissioning the Long Island and Illinois AFC equipment and LT recognized that this experience was useful. For example on the first day of the Illinois Central system five out of the seven barriers at their most intensively used station went out of commission. Quite apart from that, many of the new gates were severely tested by passengers experimenting with such things as chewing gum wrappers (rather than tickets) and many of the remaining 35,000 passengers who were let loose managed to get themselves or their luggage trapped. LT was keen to guard against anything similar causing a problem in London. There was nevertheless some hostility towards ADS, and in particular it was transparently obvious that ADS was continuing to try and extend its brief, which seems to have given rise to some annoyance. In any event, ADS seem to have disappeared by the end of 1965.

Dell seems to have been with another official in Beverley Hills in November 1965 where his surroundings seem to have inspired him to come up with a solution to the thorny question of how to determine the intermediate availability of a season ticket, which resulted in his colleague sending a telegram to London explaining the proposal (later set out in detail). This will be explained later, but the point here is that a solution now seemed possible.

There was much grumbling by some of the project team about the difficulty of dating tickets and this seemed intractable so long as the coding was included on the printing plates of the tickets where it was fixed. The Acton (and later the Chiswick) gate could read a date code where provided and eventually it was agreed that small batches of tickets would have a specific date code added

This rapid printer ticket has had a coded date added at the left hand end. The code (2012) represents the decimal number 59 which if 2-month code cycles were contemplated at this early stage is the 28th of an even month. The year appears to be 1966. This is probably a ticket printed in bulk at Chiswick Park and date coded off site. It might have been date coded by a modified printer at Chiswick, but no reference has been found to such a device.

and that on those days those particular coded tickets could be issued for test purposes.

Period tickets were still a challenge and in desperation it was conceded that several series of weeklies would be made available and issued for weeks, apparently in random order, with the equipment set to read that week's chosen code only (and the previous week's ticket for the period of overlap over the weekend). Even that was problematic as the coding was shared with the gate passes used by staff. As a test to reject invalid tickets it was just about acceptable, but it was hopeless as part of a future ticketing system.

The results of the tests at the various experimentally-equipped stations looked very promising. Apart from the obvious success from the technical point of view, the gates were (rather more importantly) a success from the operating point of view. On the first morning of operation of the inwards barrier at Turnham Green, for example, some 500 extra tickets had been sold, suggesting some laxity in the previous manual checking. Significantly these sales also stayed at a higher level, and after many weeks an additional 2300 extra tickets per week were still being sold. Obviously with the majority of passengers using the new gate it was possible for the collector to scrutinize more carefully the remainder of the tickets, mainly seasons, with the result that entry onto the system was virtually impossible without a valid ticket.

Exit gates, too, had shown their worth. These gates dealt with a proportion of the passengers the collector would previously have dealt with, leaving him more time to examine the tickets of the remainder. The real advantage, though, came from the use of the excess fare window. This advantage was twofold. Firstly, the collector was relieved of calculating and collecting excess fares which made his job easier (if only because dealing with an excess fare transaction, especially when change was required, takes both time and concentration, enabling ne'ere-do-wells to slip through without paying the right fare). Secondly passengers had to pay any excess to the booking clerk who issued an excess fare ticket for the amount required, which ticket was financially accounted for. During the first week of this arrangement at Acton Town the extra cash shown in excess fares averaged £5 a day, which then represented about £500,000 a year if this increase could be shown over the whole system.

Chapter 8
The first ‘Oxide’ tickets

Introduction

At about the same time it was conceded that the magnetic ink process was too inflexible and what was needed was a reliable system that made passive provision for reading and then re-writing code. The answer appeared to be a ticket carrying a magnetizable backing of iron oxide, rather like the tape used in a tape recorder. This could use the existing electronic decoding equipment but would require a completely new arrangement of reading heads and transporter electronics. It appears that the existing magnetic ink gates worked by passing the inserted ticket over a powerful magnet before presenting it to the reading heads, thereby imbuing the code bars with sufficient magnetism to be capable of registering with the pick-up heads. The coding on an all-magnetic iron oxide ticket would be destroyed by such a magnet, which would have to be removed before oxide-backed tickets were used. In turn this meant that gates could not read both oxide and magnetic ink tickets, so a firm decision had to be made to cease using magnetic ink and embark on a new set of experiments. A large scale experiment was now planned at Hammersmith, and matters were now getting very urgent.

From 16th June 1966 a completely new type of encoded ticket was issued experimentally, from one of the rapid printers at Earls Court. This was a yellow ticket with a coating of iron oxide on the back—a characteristic chocolate-brown coating. It was now possible to put code bars on the oxide coating electronically rather than having to use a fixed printing block, which lacked flexibility. The coding on this type of ticket was now invisible. Ordinary ticket availability information was printed on the front, as on a normal ticket.

For the future code reading equipment to do its job correctly, it was crucial that the spacing between consecutive code bars was correct. This was not a problem on the early experimental tickets because the bars were applied as a single set by a printing block. The magnetic code could not be applied in the same way and encoding could only be done sequentially as the ticket passed across a recording head and the speed of the ticket paper could vary. What was needed was a method of arranging the electronics so as to be capable of energizing recording head at precisely the moment when the position of a code bar was required on the passing ticket, irrespective of how quickly it was moving.

The method used was to link the equipment which discharged the coding to the writing heads with the mechanism of the rapid printer, using a device known as a phonic wheel. This wheel was geared to the printing mechanism and was arranged to revolve once every time a ticket was issued. As it did so, teeth on the perimeter of the wheel sent impulses to the coding unit, which fed out the code to the encoding heads. Consequently it did not matter whether a ticket was issued at an even, constant speed or not, the coding would always be correctly spaced—and this was critical to the success of automatic ticket examination. This method proved quite successful and was adopted as the standard way of encoding tickets issued from conventional ticket machines, including rapid printers.

Because the code was now electronically generated, it was practicable to incorporate a code for the date, and provision for this was made (although the facility was not actually used at this stage). The tickets were issued at the 4d (minimum) fare purely to see how they stood up to handling by passengers. During July 1966 the experiment spread to individual 4d printers at Piccadilly Circus, Blackfriars and Alperton—again just to find out how they stood up to handling.

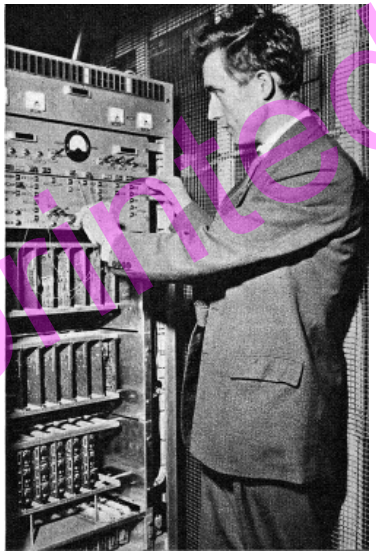
These initial tickets were primarily to check the robustness of the magnetic coding system. The actual coding system deployed was the ternary code using two tracks along the long edges. The arrangement of the coding and the spacing was similar to the binary tickets at Turnham Green but it was hoped that the oxide backed process would improve reliability and enable the ‘clock’ track also to be used to carry code, hence ternary reappeared but with

29 ‘useful’ bits and the two end bits used for direction discrimination. This profoundly increased the information that could be encoded.

The first ticket gates to accept Oxide tickets

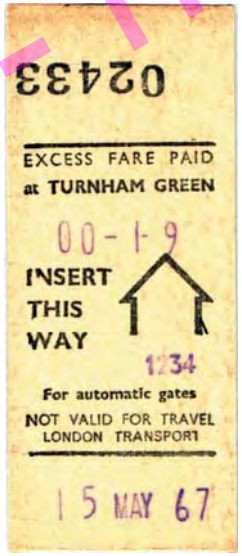
On 13th July 1966 the magnetic ink ‘Exit’ gate at Turnham Green was withdrawn from service and replaced on Sunday 17th July with new equipment capable of deciphering oxide-backed tickets. The tickets were initially issued at six stations with high sales to Turnham Green but another 34 were intended to participate later. Eventually many of these stations were equipped with switches enabling the date code to be changed, but until this was done a special ‘pass’ code was used—the Turnham Green gate would accept either form of code, what it would not allow was a wrong date code. Once more, the experiment was complicated because there were still three independent types of experimental ticket in use concurrently, viz:

1. ‘oxide’ tickets issued by stations at the Turnham Green fare, for use in the Turnham Green ‘exit’ gates;
2. yellow ‘magnetic ink’ tickets issued at the Acton Town fare (2 and 3- track types), for use in the Acton Town ‘exit’ gates;
3. yellow ‘magnetic ink’ tickets issued for use with inwards gates at Turnham Green, Chiswick Park, Stamford Brook and Ravenscourt Park.



A technician checking the coding racks for the new oxide-backed ticket gate at Turnham Green.

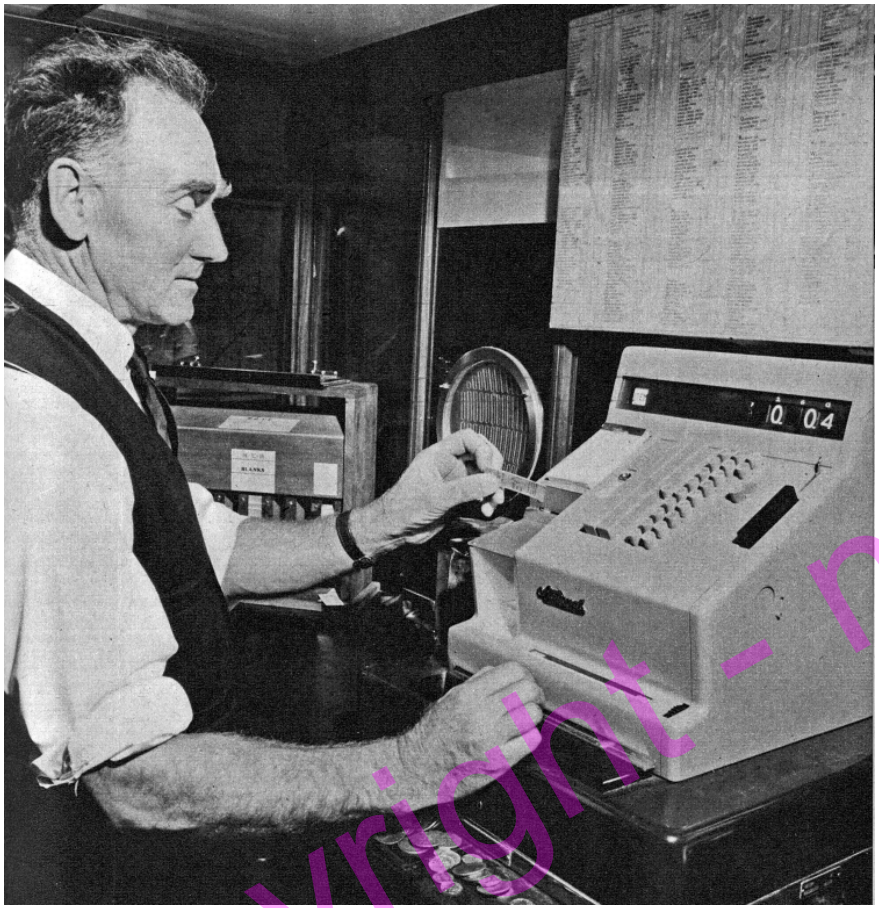
Shown above is Turnham Green shortly after the exit gate had been rebuilt to accept oxide-backed tickets. It might be seen the season ticket reader on left hand stanchion has been removed. Note also the cash register by the excess window..



An example of an exit pass issued by the cash register at the excess fare window at Turnham Green when the oxide-backed experiment started.

These tickets represent four of the six stations issuing oxide-backed tickets to Turnham Green, using the new arrow device. These were all issued by rapid printers with one of the print positions fitted with coding heads and a phonic wheel

At the latter three stations, of course, normal green tickets had to be issued for local journeys at the Turnham Green fare because the 'ink' tickets would not work the 'oxide' gate. The files record that the experiments with magnetic ink would cease at the end of 1966.



The excess fare window at Turnham Green from the inside. The clerk is inserting an excess fare exit pass into the trial cash register, having rung up fourpence. The exit passes were partly pre-printed but had the fare paid, transaction number and date overprinted in spaces provided. The tickets may have been coded in this machine (descriptions do not say) but given the limited space it is far more likely they were supplied in bulk already bearing exit gate coding.

The examples just shown are of the earliest oxide-backed tickets intended to operate the Turnham Green gate. The introduction of the arrow is of interest because hitherto there was no attempt to get passengers to insert tickets in any particular of the four possible ways of doing this and the equipment attempted to allow for that. It is possible that the modified gate had only one pair of reading heads and that for reasons of cost it was not felt worth allowing the ticket to be inserted either end, thereby duplicating the input electronics. Descriptions do not disclose any reason. This style of AFC ticket remained in use for some years and after 1968 the printing blocks were reused on ordinary non-AFC green card, which would not work any gate but served to show the level of economy LT sought to practice. The production gates for the Victoria Line allowed any ticket orientation to be used.

Chapter 9
The Hammersmith Prototype

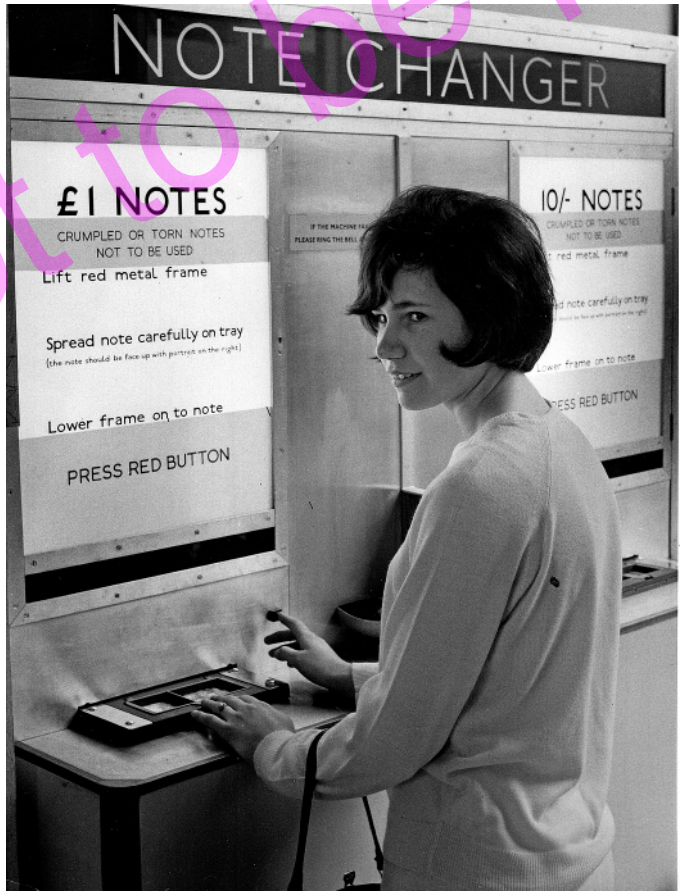
The Need for Large Scale Experiment

A review of the experimental installations was made in mid-1966 and it was decided to proceed with a prototype installation based on oxide-backed ticket technology which, if successful, would be a forerunner of the system hoped to be employed on the Victoria Line. The station selected for attention was Hammersmith (District & Piccadilly) which had the benefits of a spacious booking-hall, proximity to the existing experimental stations and the workshops in Kensington. It also had a brisk annual traffic of about 22 million passengers. A complication was that it was also an interchange station with the Metropolitan (Hammersmith and City) Line station across the road and which involved leaving LT premises, but this was not thought likely to present any serious challenge.

The experiment was intended to test the conceptual design for the Victoria Line. The idea was to sell the vast proportion of tickets from automatic machines and check them all by means of automatic barriers, both in and out. The need for an excess fare window suggested a free-standing ticket office with one face accessible from the paid side of the barrier and ticket issuing windows on the entry side. Free-standing automatic machines offering change would be available for the most popular fares and to keep pressure off the ticket windows a multi-fare machine would also be available. One or more note-changers would be installed to provide change. The conceptual design would be modified to suit each station but involve the same elements.

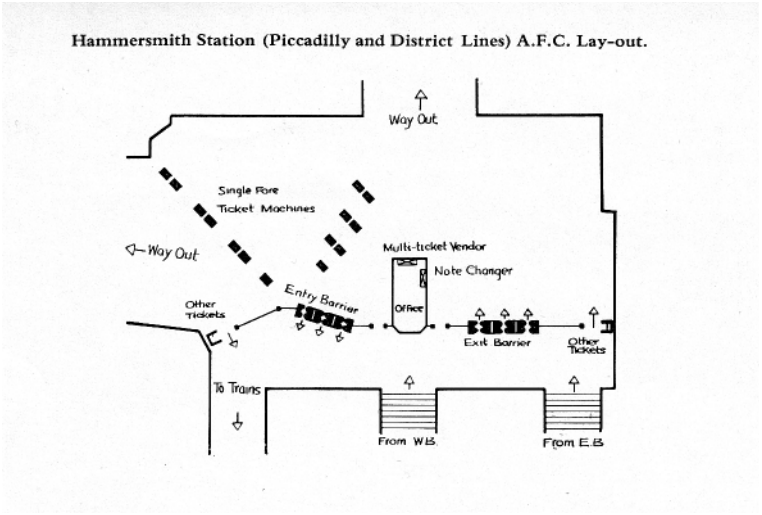
A New Standard for Ticket Offices

The station was converted in stages. Some major structural work was required first, during which the large new ticket office was installed. The first element of the new concept to be made available was a note-changing machine, which was introduced on 25th May 1966—this gave change in florins (10p) for either 10 shilling notes (50P) or £1 notes. The files report some earlier hand-wringing about note changing machines which were accepted as a useful facility but were technically very difficult to design bearing in mind they needed to be secure and reliable (and that computers were not then available)



This is the note changer installed at Hammersmith, the first bit of new equipment to be installed in the as yet unopened ticket office. £1 and 10 shilling notes each had a separate unit.

At about the same time additional automatic ticket machines were introduced to bring the total up to 14 and all but two of these (at the 4d fare) were able to give change if this was required. The machines were prominently positioned—passengers having to make a positive attempt to avoid them rather than having to deviate to use them as was so often the case at older stations.



This plan shows the final layout at Hammersmith showing how passengers were directed to buy tickets from machines.

The new ticket office shortly after opening and before much of the innovative new equipment had been installed

The new ticket office itself was commissioned on Sunday 17th July and it replaced the two existing 'Passimeter' offices. It had just two normal ticket

This shows the multi vendor machine built into the end wall of the ticket office and which, it was hoped, would become part of the standard station kit. Capable of providing tickets at 20 fares and giving change it extended the range of tickets available for vending automatically given the stand alone machine dealt with only the most popular fares. The ticket issuing logic was custom built but the actual tickets were printed by a modified rapid printer behind the fascia.

windows but in addition had one window for the issue of season tickets and also a prospective excess fare window.

On 24th November 1966 a large multi-fare ticket machine was installed next to the note changer. This issued twenty different fare denominations of ticket and accepted a wide variety of coins, giving change where appropriate.

The multi-fare machine was used in concert with a large fares list, incorporated in the front of the machine. It was operated by inserting any combination of copper or silver coins and pressing a button corresponding to the selected fare. The machine then delivered a ticket into a tray and change (if any) into another tray. If a higher fare had been selected than had been paid for, a display lit up to indicate the extra money required. If the passenger decided to abandon the transaction at this stage he could press the 'reject coin' button to lay claim to his money and clear the machine. The 'gubbins' within the machine was essentially nothing more revolutionary than a pair of rapid printers (not dissimilar to the type introduced over 30 years earlier!) connected to a coin acceptor/control logic mechanism. The machine was intended to be serviced from inside the new ticket office, and it is understood that during the first few weeks of operation the rear access facility proved invaluable to the engineers dealing with 'teething troubles'.

Ticket Gates

The exact date of introduction of the automatic inwards gates at Hammersmith is not clear beyond doubt. LT announced that two inwards gates were to have become operative from Sunday 30th October 1966. For this, ticket office-issued and Multifare-issued tickets were changed over from green to yellow oxide-backed types (except for those at the Acton Town (1/-) fare as oxide tickets would not operate the gates there). The tickets were laid out differently from the normal style and incorporated an arrow marked 'for automatic gates INSERT THIS WAY' (and in the case of tickets from the Multifare machine the 'window' number was replaced by the letters MV). Whether the automatic gates were introduced on this day the author has not yet been able to ascertain,

Top image is of the new in gates at Hammersmith, which used the deeper barriers. Lower image is of the out gates, which were of a different style. The luggage roller was a contrivance designed to encourage suitcases (but not people) to go that way rather than getting trapped in a gate and luggage remained an issue

but less than a month later the barriers were seen under covers and boards, and the source suggests that this may have been due to their inability to cope with a passenger flow of up to 5000 passengers an hour. Three inwards barriers (presumably incorporating the first two) were introduced from Sunday 19th March 1967

At first, the card stock tickets were dated by hand and then put in a hand operated encoding unit before issue to passengers. Soon after this (from 12th July) the automatic 'exit' barriers were brought into use, together with the excess fare window which was operated along similar lines to those at Turnham Green and Acton Town but with a device which could issue oxide backed excess fare tickets. This was the cash register which was an adaptation of a standard NCR design.

Tickets and the Cash Register

The use of the cash register for 'normal' tickets (also in July) was a further major innovation. Most ticket offices held stocks of up to 150 different denominations and types of ticket and every ticket of each type had to be accounted for each day, whether sold or not. With the introduction of the cash register it was hoped to cut this number down to six basic types—Adult, Child and privilege types, each in singles and returns. Unavoidably a few other types of ticket could have proved necessary. The breakthrough was that these new card stock tickets would be valueless until passed through the specially adapted cash register which would print the date and the fare, and keep a register of sales on the tally roll—saving an enormous amount of bookwork. The cash register also incorporated an encoding unit so that the ticket would be correctly encoded as well as printed as it passed through the special mechanism attached to the right hand end of the register.

Two tickets were issued for returns—the forward portion and the return portion, both were passed through the cash register the latter ticket being dealt with first. A problem arose with Child returns necessitating a fifth blank ticket known as a '*Child return'. The need for the '*Child Return' ticket arose from

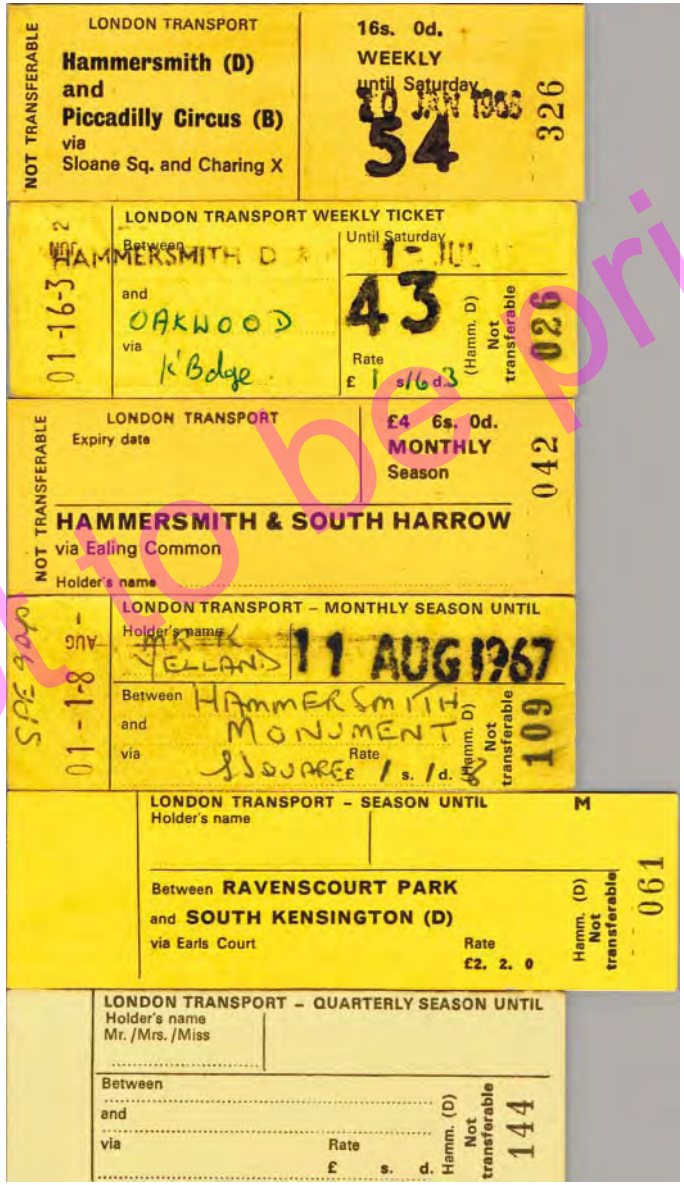
Examples of Hammersmith tickets. At top are pre-printed tickets issued from the ticket office when it opened. Returns were issued as a second portion to facilitate correct use of the gates. The lower tickets were machine issues, on left from the ticket office rapid printer and on right from the passenger-operated multi-vendor machine.

This is the inside of Hammersmith ticket office showing the clerk issuing a season ticket via a cash register. He is inserting the ticket into the encoder built onto the right hand side of the machine. To its left are the push buttons for encoding destination station, route and other detail.

the inability of the Cash Register to print halfpennies, a need which then existed as a Child's ticket was half the adult fare. For example—if the Adult Single Fare was 1/3 then the Child Return fare would also be 1/3 so both the forward and the return portions should have been marked 7½d. Since this was impossible, the practice was adopted of issuing the forward half showing 8d and the return half showing 7d—the asterisked return ticket stock being used to show any human ticket collector that the extra halfpenny had been paid.

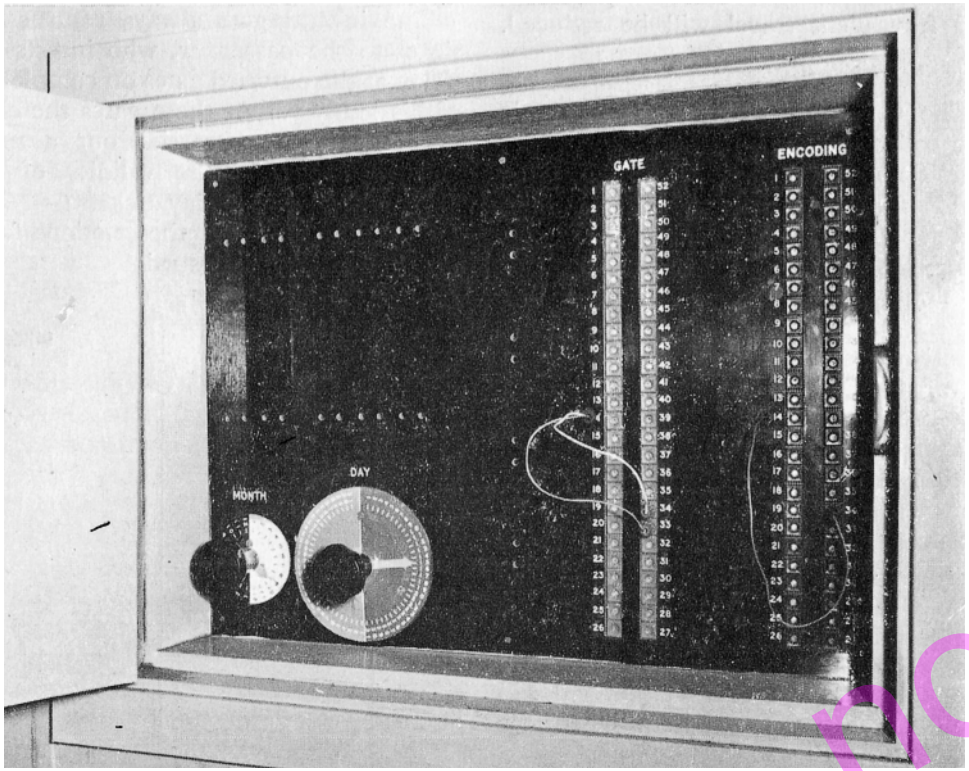
Examples of Cash Register tickets issued at Hammersmith. At left is an ordinary ticket used for single journeys (including forward half of return journeys), next is a return portion, where a return had been issued. In centre is a child variant. All these operated the gates. In green is the type used before gates were available, and at right is the excess fare ticket. It may be seen that the pre-printed details were clear enough but fare and date would be hard for ticket collectors at ordinary barriers to see easily.

One might suppose that automatic barriers needed to be warned of this inconsistency, but in practice the normal adult fares were always coded on children's tickets—possibly to avoid dealing with halfpennies or, more likely, to simplify the decoding equipment. No attempt was made to automate the issue of special tickets (Day tickets, Privilege, Cheap Day and so forth) which were issued from green card stock and had to be used via the manual barriers.

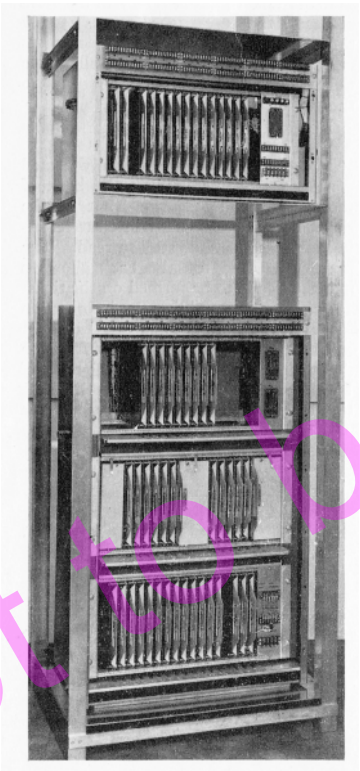


Examples of period tickets issued at Hammersmith. The top two are weeklies, the next three monthlies and the last one a quarterly. It will be seen that the blank tickets (filled in by clerk) have been issued via the cash register but the pre-printed ones already have 'value' and did not need to go through the register although they did go through the season ticket coding unit so they would operate the gates.

The Ravenscourt Park ticket arises from fact it was the same fare to South Kensington as Hammersmith and was a 'back cover' point for Hammersmith. The existence of this back cover arrangement further complicated the problem of coding tickets correctly and for this experiment they just got the Hammersmith coding



This is the station date encoder panel at Hammersmith, kept locked away where it will not get altered accidentally. On left is 24-way rotary switch selecting months 1-12 odd years or 1-12 even years. This set the current month for seasons (year of expiry used this and added the period of validity to set expiry date when new season issued). Next to it is the larger 62-way rotary switch for days, odd or even month. This was turned forward each night. On the right are two sets of 52-way sockets. Both sets have a wander lead that plugs into the current week (set here at week 34). This checked that tickets examined (left set) and new tickets issued (right set) corresponded. New tickets were issued from Friday night when the plugs were moved forward. The left set has a second wander plug inserted into the previous hole between Friday night and end of traffic Saturday as weeklies issued previous week were valid till Saturday night so it was necessary for about 30 hours to accept two different week codes.



This is the control equipment rack at Hammersmith. Many of the cards connect with the various pieces of equipment (eg gates and ticket machines) but some perform the calculation function checking dates or relating fares to station from which travelled

After a limited trial with Cash Registers, Hammersmith started to issue Season Tickets which could operate the barriers. A further cash register was added for use only with these period tickets, together with additional encoding equipment, and gradually most season tickets were changed over to the 'yellow' type. These were the same width as normal tickets but rather longer—the long-period season tickets were also plastic rather than card based

Ordinary tickets were all issued via the cash register using the date set on the station date switch, it simply being necessary to insert the correct stock and set up ticket type and price on cash register buttons. Blank seasons required price setting up on the cash register set aside for that purpose but before issue the ticket type, station of destination, route and route had to be set up on the adjacent encoder. Monthly and quarterly tickets received tickets dated one month or three months ahead (less a day), while weeklies automatically took the current week's code. The cash register printed price and date on the front and ticket was the passed via the attached coding unit before being issued to passenger. It is not clear how odd period tickets were dealt with, but they were probably ordered in advance and prepared centrally. It appears that period tickets that were already printed and priced probably just went through the encoder as it was not necessary for the cash register to record the transaction.

The seasons were at first printed on yellow plastic material and it is evident from those in author's collection that there was great difficulty avoiding smudging as the ink did not dry quickly.

Next Steps

The whole concept of automatic ticket issue and checking had become known officially as Automatic Fare Collection—AFC for short. By the end of 1967 Dell had become convinced that AFC was viable in London—if not essential. Certainly he considered it possible to equip the Victoria Line (by then rapidly approaching completion).

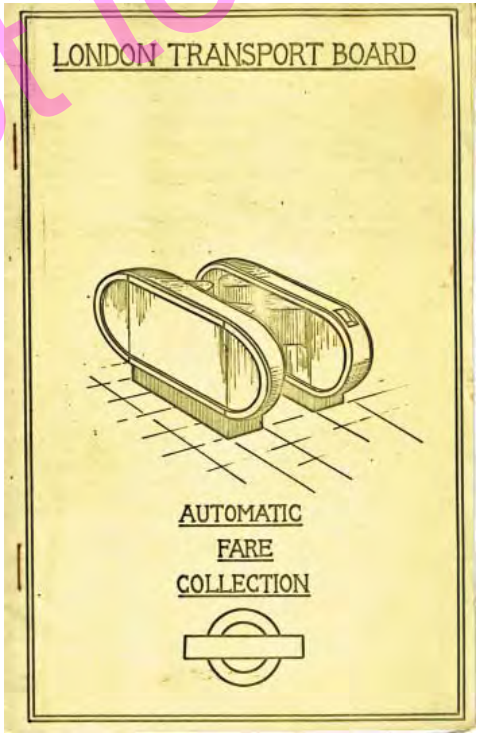
From 7th April 1968 Hammersmith issued AFC seasons to British Rail sta-tions, in addition to those of LT (although the coding used was that for the farthest LT–served station along the route from Hammersmith, apart from the handful of BR stations served by LT trains where they were included in the coding system). From then on, all season tickets issued at Hammersmith were AFC type, apart from a handful of special Road/Rail tickets which at that time were still available.

Experimental entry gate at Alperton. This had electronics similar to Hammersmith but was styled to look like the approach to an escalator. The idea was not pursued.

Before closing this section it is worth noting that from Sunday 3rd December 1967 a further experimental inwards ticket barrier was installed at Alperton (the home of one of the oxide-backed ticket experiments). This does not appear to have made a significant contribution to the development of the background electronics (it was only an in gate) and was purely to test the styling. In fact this approach was not taken forward

Other barriers are known to have been seen in public. For example there was one at the Engineers Day exhibition at the Science Museum in November 1966. There was also an experimental automatic barrier at the 'Progress Underground' Exhibition at Charing Cross station in May 1965—the fate of this barrier, a primitive magnetic ink reading type, is unknown)..

It is curious that in October 1966 the LT signal department produced this small explanatory booklet explaining how they were planning to progress the AFC project and that the little drawing on the cover is of the round-ended gate, more than a year before it was actually brought into service. We can only guess whether the gate had been built already but was not, for some reason, ready to install, or whether just the design had been completed. Perhaps it was still only a concept



The booklet does not add much to what has already been said, except it was proposed that where magnetic oxide tickets were to be held in the ticket office as card stock they would be pre-encoded in bulk *except* for the date which would be added by equipment in the ticket office. This is not what happened and no evidence has been

seen that it was tried anywhere with oxide backed tickets. Indeed it would have been awkward to do.

Engineers Day

In November 1966, the Central office of Information, on behalf of the government, organized a 2-month exhibition at the Science Museum to promote the idea of people becoming engineers. London Transport (which them employed a lot of engineers) had a stand at the exhibition, which was called 'The Engineers' Day'; the exhibition was opened by HM The Queen on 18th November 1966.

The London Transport display on Stand 12 was accessed via a new electronic ticket gate. This was used by obtaining a free ticket from a traditional-looking ticket machine to which a push button had been added to actuate the mechanism. A yellow oxide-backed ticket was then issued free, allowing the gate to be used. On the basis of the tickets obtained by the author at the time, only a 'splurge' code was applied, sufficient to inform the gate that a magnetic ticket had been inserted (though for simplicity it is possible the insertion of any ticket might have worked the gate, being at school at the time I hadn't the wit to try and ordinary ticket!). A nearby display panel indicated this was the future of ticket checking on the Underground and that the system would be used on the Victoria Line.

The ticket gate itself was the first of a new style and therefore different from those installed at Hammersmith and Turnham Green. From the limited number of images inspected the gate seems similar to those introduced as exit gates at Hammersmith in July 1967, though whether this gate was incorporated is conjecture. These were, as already indicated, not of the same design as the inwards gate.

The opening day of the Engineers' Day exhibition in South Kensington.

The latest type of AFC gate is on working display. The design appears similar to the type later employed at Hammersmith in the exit gateline. This shows the exit end.

Also shown is a ticket issued to allow visitors to use the gate.

Chapter 10
The Victoria Line Proposal

Around mid-1967 Dell had finally to persuade London Transport to press on with AFC, intending that it be installed on the Victoria Line for which the need was now urgent for a final decision as the line was to open the following year and including AFC impacted on station design. The following advantages for AFC were put forward, though none of these were new.:

1. AFC will improve the efficiency of stations;
2. AFC will speed up the movement of passengers;
3. there will be substantial staff economies;
4. fraudulent travel will be reduced.

Dell wanted it clearly understood that these advantages were expected to result from the AFC scheme as a whole, but that some of the advantages were to be gained from other elements of station automation, with stations controlled from a station operations room using CCTV. Particular points were:

TICKETS. Virtually all to be sold automatically from a wide range of individual fare slot machines or, for the little used fares, a multi-fare ticket machine. Most machines would give change and note-changers would also be provided. A small proportion of tickets would necessarily have to be issued by ticket clerks through cash registers, for example children's or privilege tickets. AFC season tickets would also be issued from ticket offices through Cash Registers. London Transport intended to sell no less than 95% of tickets by automatic coin operated machines.

TICKET OFFICES. Reduced number of 'windows' necessary because of low usage for normal tickets. Probably a special window for seasons and another one for excess fares would be needed. Each window would have a cash register.

BARRIERS. Two types of automatic barrier were considered, these being a tripod barrier and the 4-door barrier similar to that used at Hammersmith. The tripod barrier was appreciably cheaper than the 4-door type but it was considered that experience on the Victoria Line would determine future policy. Many barriers were to be reversible (ie WAY IN or WAY OUT so that peak traffic flows could be catered for.

TICKET HALLS. The layout of the ticket hall had received much thought. The ticket office was generally to be sited centrally to-give a good view of all the ticket gates and to be accessible to passengers on both sides of the barrier. At some locations the ticket office was to be situated to one side of the hall. Historically, because many of the ticket halls would have to be built before AFC had been proved, it was necessary to design them for use equally efficiently with or without AFC. Furthermore the ticket halls had to cope with layouts for 'partial' AFC and yet be capable of 'convenient' adaptation to a 'final' layout.

The above approach potentially formed the basis of a 'total' AFC system, but there were some huge practical difficulties to overcome. For a start, there was not the money for widespread installation of AFC and for the immediate future it would have to be restricted to the Victoria Line. There were also going to be problems at the British Rail interfaces, and their enthusiasm and co-operation would be essential. LT hoped, of course, that BR would take a sufficient interest in AFC to the extent where an LT-type system would be used in the London area and facilitate easy through ticket arrangements (and LT allowed for this in the ticket coding system). More subtle problems included the necessity to familiarize passengers and staff with the battery of alien equipment and to test thoroughly the whole concept of AFC under service conditions with normal ticket issuing and collecting procedures readily available as a back-up.

These constraints meant that the 'total' AFC concept would need modification in the short term, and the Victoria Line system had therefore to be designed as 'First Phase' AFC. The main changes required were the provision for varying degrees of manual ticket issuing and checking. Obviously Victoria Line stations would themselves issue a majority of coded tickets and it could be expected that after a while many users would be able to use the

gates. However this was less likely to be so for passengers leaving the station having bought tickets elsewhere. Furthermore the vast majority of season tickets (generally purchased at suburban stations) would not be of the AFC type for a considerable time.

The 'final' phase of AFC (which never came about in this form) could only take place when every possible Underground journey was covered by coded yellow tickets and this had to include all seasons and passes. When this had taken place it would prove possible to replace the manual ticket barriers by further automatic barriers. Under these conditions every ticket would be checked by an automatic gate upon entry and exit and no facilities would be provided for manual barriers. Any passenger with a defective or invalid ticket would have to see the booking clerk and obtain a ticket that would let him pass through the barrier.

Dell also gave consideration for further development beyond even the 'final' phase, as new doors would then be opened. In particular, the use of stored fare tickets would become feasible: even in 1967 stored fare tickets were considered to be the ultimate goal. The passenger would buy a special ticket encoded only with the fare paid— say £1 (a lot of travel in 1967!). When the passenger entered the system the entry station would be encoded by the barrier onto the ticket. When the person left the system, the exit barrier would calculate the fare required and re-encode the ticket with a new fare value (which would obviously be the old fare value minus the fare for the journey made). It was envisaged that these tickets could be sold at a discount and possibly replace at least weekly tickets—perhaps £2 worth of travel might be sold for £1 15 Shillings (£1.75). Whilst the Victoria Line equipment was obviously not so equipped, the equipment ordered was not wholly incompatible with such a scheme one day being introduced, though there were formidable technical obstacles still to be overcome.

Chapter 11
The Victoria Line AFC System

By now readers may not be surprised to learn that the AFC equipment was not quite ready for the opening of the various stages of the Victoria Line and that green card stock tickets had to be issued from the cash registers until the gates were ready. Automatic gates were to be provided at all stations except Finsbury Park and Walthamstow Central where the arrangements on site made provision very difficult. At Walthamstow tickets were then sold in the British Rail booking hall, and intending Victoria Line passengers had to walk along the BR platforms to reach the steps down to the Underground. Even though issued by BR the actual tickets were of the normal AFC type and fully coded. At most stations the ticket hall followed the philosophy used at Hammersmith, with automatic coin operated machines displayed as the obvious means of buying one's ticket. However, multi-fare ticket machines were not provided and booking offices were expected to deal with a variety of the less common tickets and fares for which automatic machines were not provided.

As a basic requirement was to give change, a new type of ticket machine was developed, called the SE510, which had a number of advantages over previous models. Theoretically it required less maintenance by ticket office staff during the day because the machine was 'self-charging'. This meant that money the passenger put in became available as change for following passengers, not something that could be done with the older machines without major modification. The machine only dealt with silver coinage ie 6d, 1/-, 2/- and 2/6, also 3d pieces but not coppers. When the initial order for 150 of those was placed it was not known whether or not there would be a requirement for machines to issue tickets for fares for which coppers were essential, and provision was made for some recently introduced standard 50 Volt ticket machines to be used if there was a requirement to accept coppers. In fact they were used quite liberally for the then 5d and 9d fares, with change, and also for some higher fares for which they did not give change, notably 1/- and

These new SE510 ticket machines were built as pairs and were designed to give change. Some of the units issued return tickets and had two delivery slots, one for forward and one for return portions. The cases were finished in brushed aluminium.

2/-. The 'standard' machines appeared superficially similar to the older sloping front machines but were more recent and complied with the requirement to avoid high voltage equipment in ticket halls, for which purpose they were painted silver rather than blue to make it more obvious to staff what they were dealing with. The new SE510 machines had a brushed aluminium finish and were more modern in appearance.

The standard 4-door type of Victoria Line ticket gate, incorporating illuminated arrows to direct passengers and their ticket. Usually each gateline incorporated luggage rollers, as here. It was not unkown for passengers to attempt exit this way

Where space was short, tripod-type barriers were used as these needed only one gate stanchion. They gave no indication a ticket was acceptable and tended to be slower than the standard gates.

The SE510 machines were quite elaborate pieces of equipment. In addition to the variety of coins they accepted, they gave change in whatever coins were available. If change ran out a sign lit up asking for exact fares only. These machines also utilized a larger roll of paper than the older equipment so this enabled it to survive longer without attention, which was a very useful feature at a busy station. Most of the 510s issued single tickets but a very limited number issued tickets at the ordinary return fare. In this case two ticket slots were provided next to each other, and the forward and return ticket portions appeared simultaneously. A feature of all the 510s was that where less money had been inserted than that required to issue a ticket then the money would be returned automatically to the passenger after a brief delay. This made the machine available for a fresh transaction whereas the older machines, unable to distinguish between transactions, would have kept the money, perhaps forcing the passenger to abandon it or to buy a ticket he may not have wanted.

The automatic gates were generally of the 4-door type and very similar to those used at Hammersmith, although their construction was slightly lighter and the gate-arms not so deep. The 'Tripod' type gates had the benefit of not being as wide as the 4-door type and were used at Euston and Warren Street where space was tight.

The new ticket hall at Oxford Circus. This was generally Way In only but in morning peak (as here) it was also used as an exit and about half the gates were reversible

The gates, naturally, were strategically placed. Generally, inwards automatic barriers were sited as close as possible to the ticket machines and ticket office. The manned barrier was generally sited as far as possible from the ticket office to make it just slightly more inconvenient to use than the AFC gates. There was usually an exit gate close to the booking office primarily for those having just purchased an excess fare ticket. Many barriers were 'reversible' so they

This view shows a typical gateline with centrally located ticket office. Several ticket windows are just visible on this side and an excess fare window is located on the 'paid' side of the barriers.

could be switched from entry to exit work according to the flow of traffic. At Oxford Circus the old station was converted for exit-only use and had only exit gates and excess fare offices; the new circulating area was thus generally used for entry purposes. Late at night, however, and on Sundays, a few reversible gates in the new station enabled the exit hall to be closed down completely and the entry hall catered for all traffic.

At Kings Cross a special problem arose because of the need to cater for passengers changing from the tube lines to the Metropolitan Line, a journey then requiring passengers to pass outside barrier limits. In the normal course of events any check by AFC exit gates, would consume the passenger's ticket (unless it was a season) and so two special 'exit' gates at the end of the interchange subway were provided to cater purely for interchange passengers and these returned all tickets to the passengers.

Examples of machine-printed encoded tickets used on Victoria Line. The top four are from automatic machines. The upper pair from standard 50 volt autos (machine number at top right prefixed 'A'). In the second row are tickets from the new SE510 machines (pre-fixed VX, the roman equivalent of 5-10). At bottom are forward and return portions of a 2-part return issued from a rapid printer. This is not (quite) a matched pair, but normally the rapid would print both simultaneously and they would have same serial number.

This is the final form of NCR cash register, used widely on the Victoria Line. The various blank card tickets for issuing and encoding are now stored in a rack actually mounted above the register. Just to the right, behind the ticket issuing window, can be seen the push buttons for the rapid printer.

When the north end of the Victoria Line opened the AFC equipment was incomplete and at first the tickets issued from the cash registers were printed on green card stock. The designs were similar to those used at Hammersmith but this time a much larger range of ticket types were available from the cash registers.

No such facility was provided at Warren Street where for passengers other than those holding season tickets, the previously-allowed interchange between that station and Euston Square was withdrawn on and from Saturday 1st March 1969. Had the facility not been withdrawn, the AFC gates would have collected the tickets of passengers trying to change lines. After the withdrawal of the original exit gates an unadvertised interchange facility was re-introduced.

Most booking or excess fare offices had an emergency control panel which could be used if the clerk spotted a passenger 'in difficulty' whilst trying to use the gates. The panel contained switches to open particular barriers if someone had become trapped and a microphone unit from which he could speak via loudspeakers to individual barrier positions to offer 'ex machina' condolences and advice.

Associated with each automatic barrier position was an illuminated sign suspended from the ceiling. On the earlier standard installations the sign displayed IN or NO ENTRY depending on the directional flow of the gate as one approached. The later installations employed a downwards pointing arrow or a cross sign which had the same respective meanings.

GREEN PARK STATION

NEW AUTOMATIC GATES

Please read this carefully

In the near future, automatic ticket-operated gates will be brought into operation in the ticket hall at Green Park station

All passengers holding YELLOW tickets must pass through these gates in whichever direction they are proceeding. The gates will be marked IN or OUT indicating the appropriate direction; those with a red cross above them are not available for use.

1 To operate the automatic gate, insert your YELLOW ticket in the slot indicated. If your ticket is valid the gate will open for you to walk through. When starting your journey at an 'inwards' gate, your ticket will be returned to you to pick up as you pass through the gate. When you have finished your journey, valid single tickets will be retained by the machine on the way out, and the gates will open for you to pass through. Season tickets, however, will be returned.

2 If, on the Way Out, your ticket is not valid, it will be returned to you and the gates will remain closed. You should then take your ticket to the EXCESS TICKET window where you must purchase a ticket for the value of excess fare due, using the ticket purchased to pass through one of the automatic gates. If you have travelled without a ticket you must purchase one at the EXCESS TICKET window and proceed as above.

NO EXCESS FARE WILL BE ACCEPTED AT THE MANNED TICKET BARRIERS

3 *If your ticket is not coloured yellow*, pass through one of the barriers manned by ticket collectors. If excess fare is due you must go to the EXCESS TICKET window and purchase a ticket which will enable you to pass through one of the automatic gates.

A reminder – NO EXCESS FARE WILL BE ACCEPTED AT THE MANNED TICKET BARRIERS.

Insert ticket here

OXFORD CIRCUS STATION

NEW AUTOMATIC GATES

Please read this carefully

STARTING NEXT SUNDAY, automatic ticket-operated gates will be put into commission in the new ticket hall at Oxford Circus station.

All passengers holding YELLOW tickets must pass through these gates in whichever direction they are proceeding. Gates will be marked IN or OUT to show which should be used. Gates with a red cross above them will not be available for use.

1 To operate the automatic gate, insert your YELLOW ticket in the slot indicated. The gate will open for you to walk through. If you are starting your journey entering the station, your ticket will be returned for you to pick up as you go through the gate. On the way out, single tickets will be retained by the machine; season tickets, however, will be returned.

2 *If the ticket you hold is not coloured yellow*, you should pass through one of the ticket barriers manned by ticket collectors; one on each side of the ticket hall.

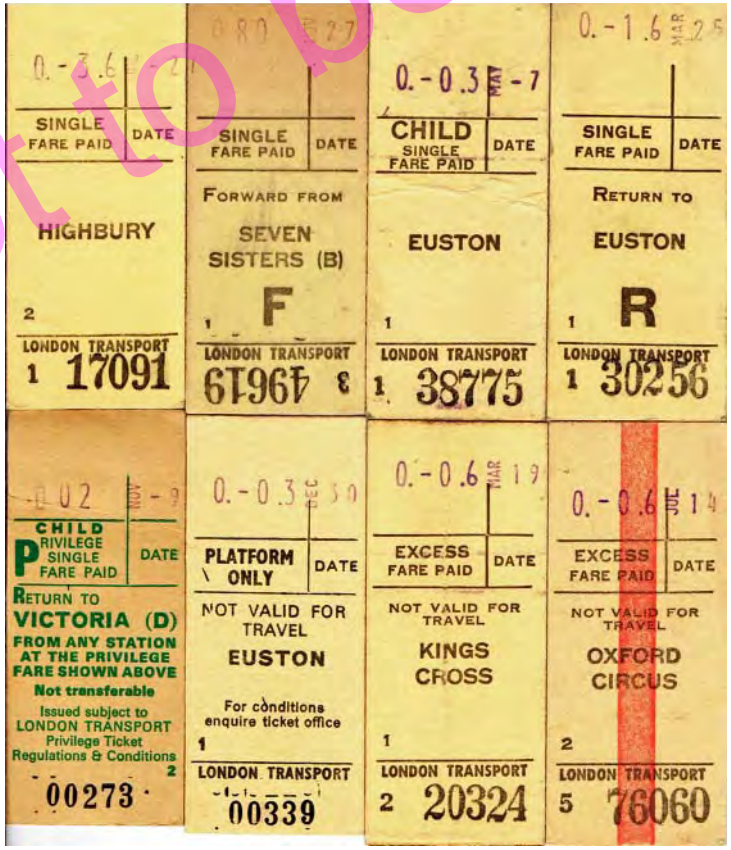
FROM NEXT SUNDAY, *no passenger without a valid ticket will be able to pass through either the automatic gates or the manned ticket barriers.*

Passengers leaving the station who are in possession of a ticket which is not available at Oxford Circus or who have travelled without a ticket must first go to the window of the ticket office indicated by the sign EXCESS TICKETS opposite the escalators where they must purchase a ticket. This will enable them to pass through one of the automatic gates. *No excess fares will be accepted at the manned ticket barriers.*

Insert ticket here

(Automatic gates will be installed later in the old ticket hall)

Prior to the opening of the southern end of the Victoria Line a poster and leaflet campaign was undertaken to get passengers used to the approaching installation of automatic ticket gates.

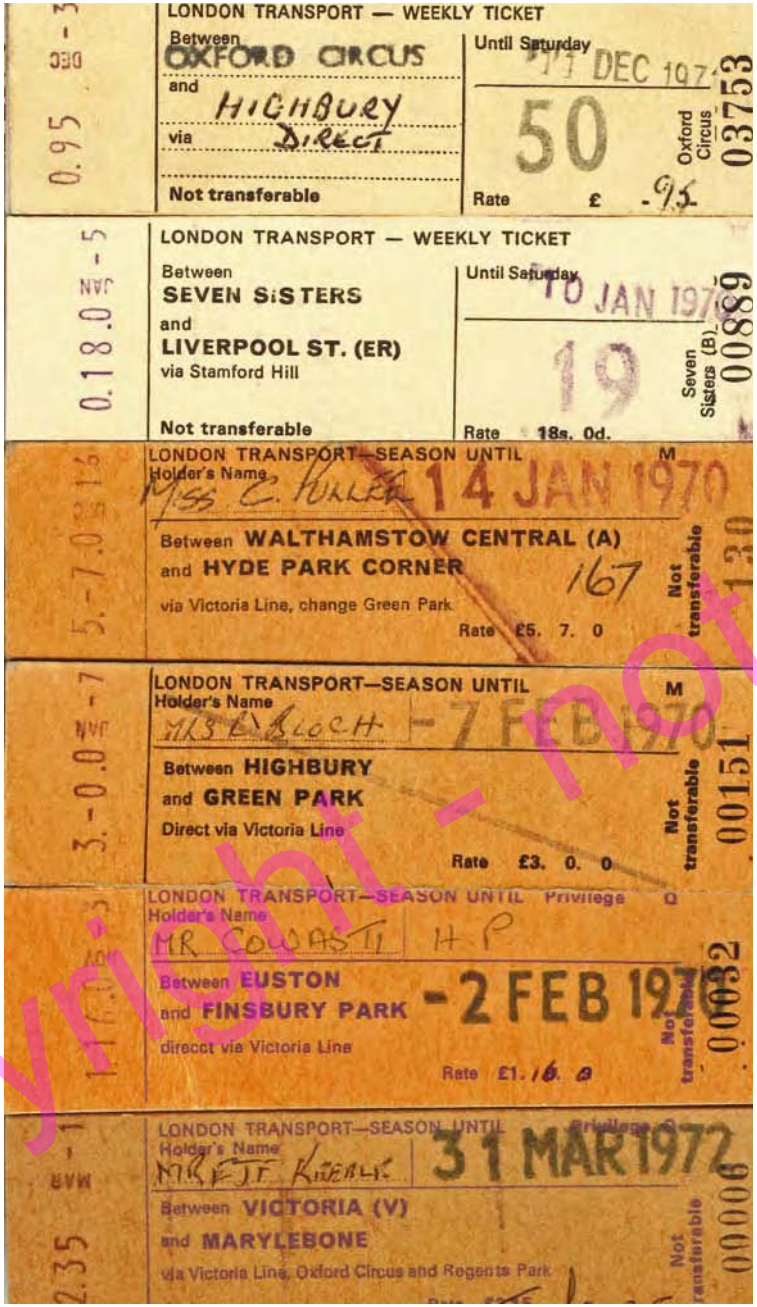


Cash Register coded tickets. At top the usual single and return tickets, with one of the many child variants. At bottom one of the various privilege tickets, a platform ticket and excess fare receipts (exit passes). After a short time it became the practice to print a vertical red stripe on these.

A selection of period tickets issued for use in the Victoria Line ticket gates.

At top are two weeklies, the first a blank and the other pre-printed. These were printed on normal ticket paper but were longer than day tickets. Unlike the Hammersmith experiment, all these tickets were accounted for by the cash register.

Below are monthly and quarterly examples. This time the paper has been slightly plasticised to make them more rugged, but they still quickly showed signs of wear. Hard to say whether they were darker when issued or whether the medium has darkened with age.



This ticket, produced with gold print for guests attending the Victoria Line opening, is representative of several produced for openings and rehearsals. These were coded up as season tickets valid on the day

Design Centre

Between 21st August and 28th September 1968 London Transport and the Council of Industrial Design organized an exhibition at London's Design Centre in Haymarket. The purpose was to show off and explain the new design features that would be found on the new line, the first part of which was due to open in September.

As part of this, London Transport provided a ticket machine and ticket gate. The gate appears to have been of the same type produced for Victoria Line stations and may indeed have been so used after the exhibition closed.

View of the AFC entry gate on display at the Design Centre and the ticket machine, fitted with push button, that issued free tickets to operate gate.

On left is view from exit end of the Design Centre gate, with visitor passing through. At the bottom is an example of the ticket used. These were not electronically dated; in fact only a 'splurge' code was used, sufficient to actuate the gate reliably every day without the complication of coding and the problems that would have incurred.

Chapter 12
Extension Of The Victoria Line System

After many months of operating experience with the new equipment many problems highlighted themselves; for example, far more people became trapped in the 4-door barriers than were expected. This particular problem was largely due to people's tendency to precede or pursue themselves with amazing selections of general impedimenta—usually, of course, briefcases or suitcases—and this confused the equipment. After many trials the mode of operation of the gate mechanism was altered so that the first pair of gates in each barrier did not close behind a passenger as hastily as they had done, and the capture rate dropped. Much effort also went into rectifying ticket encoding faults—some of these were due to equipment problems and some to staff errors.

Whilst adjustments to the AFC system were being made a small number of busy stations started to issue AFC coded tickets at fares covering Victoria Line stations; this was intended to increase usage of the automatic equipment. This was usually a two-stage process. The first stage caused tickets to be issued with a fixed unchangeable code at particular fares. As the date could not be changed a master 'date' code was applied which would be acceptable on any day (the tickets were visibly dated with the correct date for manual inspection). The second stage involved the fitting of date switches in the ticket office; these switches had to be altered each day, following which the proper date code was encoded instead of the master code. On 20th December 1969, for example, 28 stations commissioned date code switches. In general no additional automatic barriers were installed.

One of the features of the Victoria Line was the heavy through BR season ticket traffic with which the AFC barriers could not cope. A variety of stop-gap measures were therefore considered in an attempt to reduce the level of manual checking these tickets caused. Tickets to BR stations could of course be of the AFC type, but most through season tickets were issued by British Rail and were of their normal card type. Following agreement with BR, experiments took place at several Southern Region stations which proceeded to issue of LT-style AFC Season tickets for the whole journey. The only problem was that having been issued by BR the tickets were not coded, and it was necessary for passengers to call at the LT booking office at the exchange station to have this done (on their first journey only) if they desired to avail themselves of the improved speed of the AFC gates thereafter. The coding put on the ticket only applied to the LT portion of the journey.

As a further experiment to increase gate usage, AFC style seasons were issued from Sunday 21st June 1970 at Wood Green, Turnpike Lane and Manor House for Monthly and Quarterly tickets to Green Park. Again passengers had to call in at Green Park Ticket Office to get the tickets encoded the first time they were used. This particular scheme lasted just over a year (the equipment installed to enable ordinary tickets to be issued and coded AFC-style was not capable of adaptation to issue season tickets). Whilst Green Park was on the Piccadilly Line it was presumably expected that many passengers would opt to change at Finsbury Park for a shorter run on the new line.

Amongst the teething troubles passengers encountered with their new tickets was, at first, a propensity for some of the keener ticket collecting staff to cancel AFC tickets on entry by punching a hole in them with their ticket nippers, and there were several requests for staff not to clip yellow tickets (which could mangle the code).

Further problems then came to light with the automatic barriers. Passengers seemed to have some difficulty in using the tripod gates, and this caused undue delay. The problem was probably partly due to the lack of any obvious sign that a valid ticket had released the barrier, but there was also a tendency to be put off by having to push the barrier round as one passed through. An experiment to solve this latter problem was introduced at Euston in 1970 by motorizing the arm in such a way that once having pushed the barrier arm the device rotated 'with the passenger' as he or she passed through.

Always-open gates trialled

The 4-door gates also continued to exhibit undesirable behaviour. In addition to residual tendencies to capture people, the gates suffered heavy wear and as a result of this some experiments were carried out at Seven Sisters with the barriers arranged for 'open mode' working. In this mode of operation all four doors were normally open. From 8th November 1970, passengers inserting a valid ticket caused a green lamp to be shown, indicating a valid ticket, and they then just walked through with the barrier remaining quite impassive. On the other hand, passengers attempting to walk through without having first inserted a ticket, or having inserted a spurious ticket, would be abruptly brought to a halt by the gates closing in front of them; in this case the gates would not re-open until a correct ticket was inserted. As a preliminary warning a red light would be shown if an incorrect ticket had been offered. This experiment showed some promise and was extended to one or two other places, including Green Park. The number of gate-movements was very substantially reduced with this system but inevitably the new arrangements did create problems of their own.

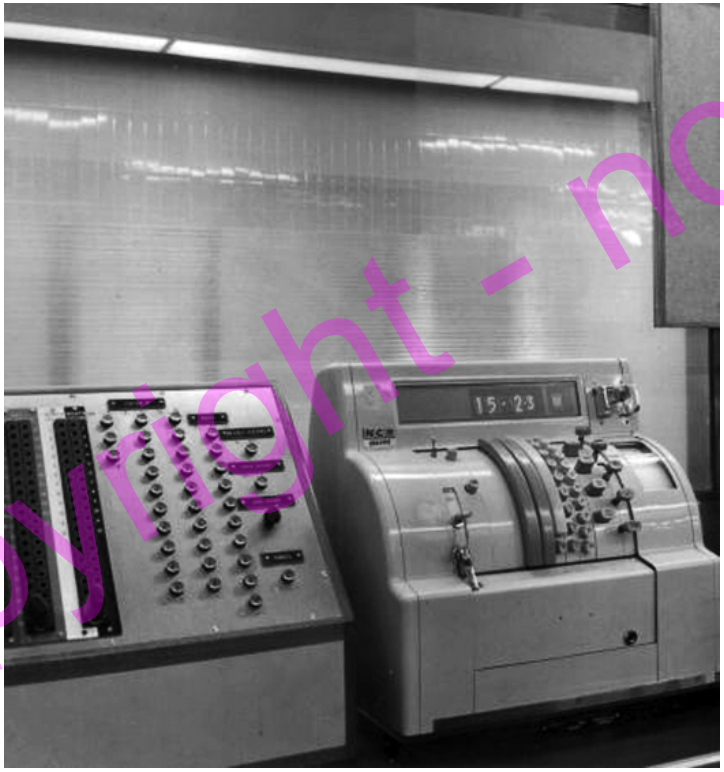
The gates at Green Park after conversion to normally open mode, the obvious tell-tale being the lamp units fitted on top. A green lamp meant proceed and red meant stop (and the gates would close if a passenger then attempted to proceed). Leaflets were produced to inform passengers, the one shown is for Seven Sisters where a similar alteration was made.

Decimalization (Rail)

Decimalization of Britain's currency caused some interesting complications. Prior to 'D' day on 15th February 1971 (or 14th on the Underground) a strategic fares revision took place which on the Underground employed a fares scale rising in shilling (ie 5p) steps, and tickets were printed with the fare shown in both shillings and new pence. Once the new scales had been introduced the range of coins accepted by ticket machines was largely cut down to decimal-compatible coins (ie 1/- [5p] and 2/- [10p]); coppers were not generally acceptable. Change giving facilities were also reduced. On the SE510 machines the acceptance of half-crowns had already been withdrawn from mid-1969 (when that coin was demonetized). Sixpences (worth 2½p) continued to be legitimate currency for a further year or so, and although not part of the fares structure some machines continued to accept them.

To avoid the need for mass alteration to the printing and accounting units of cash registers, some curious intermediate changes had to be suffered. From 20th November 1970 they were progressively altered to a decimal compatible format. Cash registers at Excess Fare positions were temporarily adapted to show the fare paid in (old) pennies only. Thus a fare of 1/8 would, for example, be shown as ·20. Season ticket cash registers were converted to show the fare in shillings only, so that a fare of £22/10/0 would have been shown as 4.50—the decimal point, of course, being ignored. After 'D-day', the

numeric point positions assumed their correct values of (new) pence or pounds and (new) pence. These figures were printed on the tickets themselves and it is of interest to note that at some stage, probably when the above alterations were made, the facility for showing (new) halfpennies was installed, doing away with the need for the *Child stock cash register tickets. The author has as yet been unable to establish whether the 'normal-ticket' stock cash registers (ie those vending single/returns etc) were altered in advance of D-day, nor has the author established whether decimalization caused the last death throes of the few change-giving facilities or whether this died from some other cause (a note change-giving machine had been put in at Oxford Circus shortly after the rebuilt station opened but as a general rule they were not installed as first recommended).



A production cash register with (to left) season ticket code setting unit (with a less home made appearance). The three sets of buttons on left set up 3-fig destination station, the next column set one of ten route codes and buttons on right the season type and a local/ distant switch.

More Ticket Machines

When the first sections of the Victoria Line opened in 1968/9 a large number of ticket machines (designated SE510) were brought into service. At many stations on the line there were also old sloping front machines from the 1940s and 50s, rebuilt to provide tickets at some of the more popular fares and fitted with ticket encoding equipment. Decimalization and the disappearance of the coinage to which the mechanical coin selectors were best adapted, in addition to advancing age, suggested more new machines would be needed. In addition it was becoming apparent that it would be necessary in the foreseeable future for machines to take 50p coins, which the old machines could not.

This led to orders for 100 new ticket machines designated SE610 machines, the first put on test towards the end of 1969. These were of similar style to the 510s but were only single-unit machines, had no return ticket slot and were designed to accept 5p and 10p coins and give change in 5p coin only. These were built by Brecknall, Dolman & Rogers and replaced older machines around the system, not just on Victoria Line. At about the same time these entered

A typical bank of SE610 ticket machines of 1969/70 origin.

service the specification was finalized for another new design, the SE710, which was similar in appearance and functionality but had a different mechanism that could accept 5p, 10p and 50p coins and give change, if required, in 5p and 10p coin. A prototype was tested shortly afterwards and a large number of new machines was ordered (which is as well, owing to rapid price inflation tending to require more 50p transactions and fares increasing in 10p steps, rendering the 5p coin of diminishing importance.

Experimental multi-fare machine at Euston in 1971

Early in 1971 an experimental multi-fare ticket machine was introduced at Euston. Although 16 fare buttons were provided, it appears only eight were in use, providing tickets at fares from one to seven shillings (and 1/6) and accepting three pre-decimal silver coins. Tickets were printed and encoded by the machine. The fate of this experiment is not known but multi-fare machines were not trialled again for some years and like earlier attempts it was probably found too slow in busy traffic conditions.

The penultimate design of ticket machine that might be said to be from this generation was the SE910. This represented a significant development in that instead of traditional printing plates the machine was equipped with a dot-matrix type printer. This was found just as effective in issuing tickets but had the advantage that during a fares change it required a software update rather than new (or changed) printing blocks. some of them also had an electronic coin acceptor unit which was less temperamental than the old

These are preserved free-standing ticket machines at the LT Museum (having not found useful images in service). On the left is an SE1010 electronic ticket machine that used a matrix printer making it easier to vend more than one fare value. This machine could issue any one of ten different types of ticket and give change. To its right is an earlier model (probably an SE910) that could issue only a single type. Both would accept all five coins up to £1.

mechanical types and could be configured quite easily to accept a wider range of coins than hitherto. Indeed the raging inflation during the 1970s was giving rise to a huge problem as many of the pre-1970 machines could still only take 5p and 10p coins, to a maximum of 40p, whilst typical fares had risen to much more than that and as a result the ticket offices became swamped whilst the machines were under used.

An SE 1010 machine was available in small numbers from about 1982 to replace less flexible machines but once the new Underground Ticketing Scheme was launched further development of stand-alone equipment like this ceased. Some effort was made to upgrade retained earlier machines to accept £1 and 20p coins which were not expected at time of decimalization.

Standard Victoria Line gates being installed. Photo serial number comes from batch in June 1971 for Brixton extension and is probably one of those stations. In this view the gate transporters are visible as is the general disposition of the equipment. The air main and wiring to the AFC room ran in a trough under the floor.

Chapter 13
Second Thoughts

The position in 1970

A number of factors influenced longer-term AFC policy. First was the retirement of the Chief Signal Engineer, Robert Dell, who departed the scene at the end of 1969 and whose enthusiasm for the new technology, and standing amongst his executive colleagues, was not shared by his successor to the same extent. Secondly we have the transfer of the organization to the Greater London Council (GLC) which had responsibility for broad policy but subjected LT to a great deal more financial scrutiny than the ministry had beforehand, though it took a year or so before the GLC had the measure of LT and its methods. It would be fair to say that LT was not very keen on the close interest that was being taken in its operations and the introduction of political considerations to what had previously left to its own judgement. For its part the GLC saw increasing quantities of ratepayer's money disappearing into the LT monolith without necessarily getting back in return either what was promised or expected.

It was obvious to LT that the Victoria Line AFC system could not be left as it was once the Brixton extension had opened. It was pointless having a system that electronically checked tickets on only one line; it was not saving any staff, its effectiveness was severely undermined by the large volume of non-coded tickets, it was not very flexible and there were problems with reliability. LT knew (and had always known) that the true value of an automatic system could only be achieved if the whole system was gated and all tickets were checked. In the short term at least this was not going to be possible, and there were mounting doubts the technology was up to the job anyway.

Taking Stock

An essential prerequisite to possible extension of AFC throughout the Underground appeared to require a comprehensive review of fare collection methods, including an examination of the operational performance of the existing AFC equipment. In addition to the Victoria Line (including the Brixton extension) the only other station fully equipped was Charing Cross (now Embankment); however, additional installations were being planned for Marble Arch and Piccadilly Circus. Nevertheless it is convenient hereafter to refer to the technology thus far as 'the Victoria Line system' and it is this that the review would have addressed.

But in June 1971 (before the results of the review were known) the GLC authorised LT to spend up to £675,000 on installing further AFC equipment at a number of heavily used stations—this would have brought the Executive's total investment in this field up to about £4,000,000. The LT view was that at certain busy sites AFC was probably justifiable and if the capital was available years of experience suggested it was better to spend it in furtherance of some longer term objective.

The money would have been spent on installing full AFC equipment at five major sites (Waterloo [Shell building], Notting Hill Gate, Earls Court, Waterloo [Main] and Holborn). In addition a further 67 stations would be equipped with AFC ticket encoding and dating equipment, thereby issuing yellow tickets which would be acceptable at all the fully equipped AFC stations and so making better use of the existing AFC installations.

It was expected that the additional equipment would create an increased revenue cost (mainly staff) of about £155,000 but that gains from reduced fraud of between £200,000 and £250,000, would more than offset the costs. At the time it was felt such a margin was sufficient to justify the capital expenditure of well over half a million pounds.

This extension of 'Victoria Line' AFC was not to be. As the AFC review progressed, the emerging facts were to somewhat dampen the initial enthusiasm. Not only did the review arrest moves towards system-wide expansion of

'Victoria Line' style AFC, it raised serious questions about the success of the programme thus far.

The points the review brought out were as follows.

1. All the existing AFC gates required manned barriers in parallel to deal with non-AFC type tickets. Even if all LT-issued tickets could be directed through the AFC gates there remained a very large number of BR through seasons to be catered for. Little progress had been made in gaining any commitment from BR to issue compatible tickets, and in their absence it was not seen how manned barriers could be withdrawn (although BR was aware of the technology and had indeed installed a broadly similar AFC system of their own in Glasgow).
2. Given that parallel manned barriers were provided, it was proving extremely difficult to persuade all passengers with AFC tickets to use the AFC gates. The result was that the anticipated degree of fraud resistance of the new barrier lines was not being met. Among the reasons which were speculated were a natural resistance to change, a 'too complicated' appearance, and an easy channel for opportunist fraud. This did not auger well for future installations. Clearly all the unfortunate shortcomings of manual ticket checking were bordering on being imported into the AFC age. On reflection, improved publicity and targeted enforcement were, however, not impossible options if the will were there. One might with hindsight also query 'resistance to change' in the context of passengers at new stations on a new railway.
3. A study of system reliability led to the unfortunate conclusion that the AFC system had become too dependent on 'manual servicing and other manual intervention' and either despite of this, or because of this, the system was failing to perform at the very high levels of reliability necessary if the passenger is to enter and leave the Underground successfully and without incident every time! This factor of unreliability inevitably caused a proportion of passengers to avoid automatic barriers, especially exit barriers, putting an extra burden on the collectors (some simplification, including conversion of 4-door barriers to 2-door, had made some improvement).
4. In association with point 3 there was an emerging problem with correct ticket encoding where, for example, staff occasionally forgot to alter date switches or otherwise incorrectly encoded a ticket (a not wholly straightforward process!). So far as the passenger was concerned this either meant that his ticket would not work at all or, in the case of a season, it might work in an apparently arbitrary manner (a possibly disquieting feature in a ticket costing a lot of money).

In the face of reality there was little option but to reconsider the approach to AFC. Clearly the most pressing immediate requirements were a significant improvement in system reliability, coupled with an improvement in control at manned barriers (for as long as these had to be provided). Matters now resolved themselves into discussions about the long term nature of AFC on the Underground, and short term solutions to immediate problems. The simple reality was that with only a kind of 'AFC-lite' many of the station functions had not changed very much, including the need for heavy manning of manual ticket barriers and ticket offices. Moreover the system itself, in this pre-computer age, was inflexible and seemed likely to inhibit fares innovation rather than helping it as first hoped.

Change of Course

After some contemplation, it dawned on LT that two things had to be done. The first was to make substantial improvements in the way the existing equipment was managed in order to improve reliability, reduce fraud and possibly its operating cost. This would have to include rethinking the best way to make use of the budget that the GLC had just made available and which, fortunately, included a degree of flexibility in how it was spent. The second

thing was to establish and set out with justification and costing whatever emerged as the long term aspiration for automated ticketing. In doing this it was already obvious that the GLC would be critical about short term spending if the long term requirement rendered it abortive and if it was incompatible with future BR ticketing systems (which was not then clear). By August 1972 matters had become slightly clearer.

Short Term Plan

The five ticket halls already disclosed to the GLC in 1971 have already been mentioned but it was now decided to add Hammersmith (D&P), High Street Kensington, Trafalgar Square and Tower Hill to the list. The first was included in order to replace the experimental non-standard equipment and Tower Hill because it was a spacious new ticket hall designed to accept AFC and already equipped with ducting and an air main. These stations would make use of gates already in store.

Importantly it had by now been decided that much of the complexity (and unreliability) of the Victoria Line system came about by the need for complex coding and fare calculation required by the exit gates and there was an emerging feeling that if more effort were placed in checking everyone had a ticket before they entered the system then it would disproportionately reduce overall fraud. It was therefore decided not only to install only entry gates at the additional stations but to withdraw the existing exit gates, removing a major source of unreliability. At the quieter stations removing exit gates would divert traffic through the existing manual barriers but at busier stations additional staff would be needed. It was hoped the extra cost would be more than covered by savings elsewhere.

The removed exit gates would be redeployed to additional stations where it was felt they would be most likely to reduce ticketless travel if reused as entrance gates. These were planned to be Sloane Square, Turnpike Lane, Wood Green, Morden, South Wimbledon, Colliers Wood, Tooting Broadway, Tooting Bec and Balham. At this stage it was still expected tickets would be fully coded and the new gates would fully check date and ticket type.

Another significant change would be the withdrawal on expiry of the special AFC weekly and season tickets and replacement by ordinary card tickets still used at non-AFC stations. Naturally this would increase the load through the Way In manned barrier but this was felt justifiable because of the complexity and unreliability of the coding system. Some special staff passes remained in use for several years more though.

The authorized plan included installation of ticket coding equipment (but no gates) at an additional 67 stations in order to make more productive use of the existing exit gates, where installed. Now the exit gates were to be withdrawn there was no point in adding the coding equipment and it was dropped from the programme. This plan was costed at £440,000 (including an element of inflation) and used all the gates available. LT indicated it would refer back to the GLC before proposing to order anything more. In the meantime this reduced programme was expected to deliver around the same benefits.

Longer Term Aspiration

The longer term plan (which for the moment I will call future system) harboured an intention to abandon traditional single and weekly tickets and replace both by a new form of pre-paid ticket that could be sold, undated, singly or in bulk, would be transferable, were usable to start a journey anywhere. When sold, the face of the ticket would bear only the fare value and ticket type and a simple electronic code indicating that it was an acceptable Underground ticket. As sold the ticket was not valid for travel until validated. This would be done in a new design of ticket gate that would imprint on the face of the ticket the date and the station of entry, at the same time stripping the code, preventing reuse. The ticket would be collected at the end of the journey with the usual manual check. Automation of exit gates was not dismissed but was not at this stage thought practicable with so many BR through ticket issues and there was not the confidence that the technical problems of coding would result

in the required reliability so this was rather placed on the back burner. It was envisaged that the new tickets could be sold in bulk, at a discount equal to or perhaps greater than the discount given by the weekly tickets they would replace, and help take the load off ticket offices at the busiest times.

Significantly, the earlier stated ideal of stored fare tickets did not feature in the new 'future system' plan. Many, but by no means all, of the advantages of stored fares were now thought achievable by selling tickets in 'carnets' as just described, and the complexity of stored fare equipment, which in any case demanded complete gating, including exit gating, was probably viewed as over-ambitious. LT at that time had not attempted to encode tickets actually in the gates and there were some real challenges to doing this.

Mentioned once in the report to the GLC about emerging thinking was the possibility that these blank pre-paid tickets might be usable on buses (the GLC very much liked this aspiration). More information is given in Appendix 3 about what the buses were doing, but at this stage the introduction of automated ticketing on buses was problematic and the bus business was open to a technical solution (not found for some years) to the problem of excessive boarding times on one-person-operated front-entrance vehicles. The challenge to a joint ticket product was that at that time bus and rail fares for the same distance differed and this price differential was a tool used both to maximise fares yield and to manage differential loadings across the modes to the benefit of London Transport as a whole. Small numbers of jointly-usable tickets were not a problem but a popular bi-mode product at that time would have been complicated, so it was thought.

System 'C' and the Interim Solution

The AFC team at LT had evidently come up with some descriptive labels for the various options for AFC but as events unfolded there was a degree of confusion about what label described what system. So far as the submissions to the GLC are concerned it appears that the long term plan just described was termed System 'B' (the large scale use of blank single journey tickets) whilst the interim solution was termed System 'C'. It is not helpful to discover that the label System 'B' was little used after 1975 and that System 'C' itself became mired with more than one meaning, but as LT and the GLC so freely used the term I shall also do so.

The 1971 authority to spend £675,000 came with a requirement to report back to the GLC the result of this investment before embarking on anything new. LT was therefore unable to proceed with any widespread investment in System 'C' for several years but used part of the budget for development work necessary to design a new automatic gate and various ancillary equipment that appeared likely necessary, and experience of its use in service. Beyond that a number of low-cost changes were made anticipating that System 'C' would go ahead.

The first public sign that AFC policy had changed was when Pimlico Station (a late opener on the Brixton extension) opened to Traffic in 1972—no exit gates were provided. Already noted was the withdrawal (also in 1972) of the exit gates where they had been installed and their reuse elsewhere. The issue of return tickets by coin operated machine also stopped. A number of season ticket cash registers made redundant by withdrawal of AFC seasons were made available for use elsewhere for issuing and coding card stock tickets. A little later, cash registers at excess fare windows were similarly redistributed and they were replaced by much simpler 'Almex' bus ticket type machines which issued highly inferior, virtually unreadable paper receipts.

LT did not go back to the GLC until June 1974 with a worked up plan for System 'C' and when it did no explanation was given as to what the results were from the £441,000 already spent, which did not help to make the case for spending even more.

There was no change to the long term vision but the interim System 'C' solution had crystallized and had (to an extent) been calibrated by means of some experiments. In essence it proposed widespread introduction of Way In automatic ticket gates that would check all single tickets issued at those stations. Other tickets would have to go via a manned barrier but in order to maintain adequate control over inwards inspection it was intended to install

tripod type gates that would be released by the inspection staff when satisfied the ticket was valid (the tripod was released by a pedal-operated switch).

Such a pedal operated turnstile arrangement had been tested at Seven Sisters for over a year, and at Leicester Square since January (1974) and were regarded as 'effective' solutions to the problem of ticketless travel. Tests at Leicester Square suggested a 15 per cent improvements in revenue collected, 'without imposing inconvenience on passengers', though this increase was thought untypically high.

The problem of effective inspection at exit gates received much thought too. The use of pedal-operated gates was considered but dismissed. Firstly it was believed that with tight entry control the requirement for very tight exit control was lessened. Secondly there was not thought to be the space available at many stations without incurring high costs. Thirdly the costs of staffing the number of barriers required would be disproportionately high given the number of tripods needed, and fourthly at escalator stations there would be flow (and safety) challenges given that flows through the tripods had at all times to be greater than the numbers being delivered to the top landings by the escalators. It was inevitable that ordinary manned barriers would have to be used. However tests revealed that in a typical arrangement of two ticket collectors boxes opposite each other, the ability to perform a proper ticket check was much enhanced by installing a barrier or railing along the centre, breaking the irregular flow into two distinct streams. Such an arrangement had recently been installed at St James's Park and was found very effective.

None of the inwards automatic barriers needed the sophisticated coding used on the Victoria Line and for the time being the interim scheme envisaged only a simple station code being deployed, without even an electronic date check. Machines would code on issue but for simplicity card stock tickets would have to be delivered pre-encoded.

Gating the System

LT worked up a proposal for complete gating during 1973. The plan was to install gates according to the following programme.

Year	Stations	Gates	Validators
1974	31	84	3
1975	35	113	-
1976	44	139	2
1977	45	153	-
1978	45	133	11
Sports		41	-
Total	**200**	**663**	**16**

The number of validators is an absolute minimum and there would probably have been more than one per site at several stations. 'Sports' means extra gates required to handle traffic at sporting engagements at several stations and which would not necessarily have been installed with the regular gates.

Omitted from the list are a number of difficult stations which would have required special treatment, and the Victoria Line stations where it was hoped to be able to reuse the existing gates by installing a special add-on unit to the ticket transport mechanism to perform the required System 'C' functions.

The proposal for full System 'C' installations made to the GLC in summer 1974 proposed equipment at each of LT's 250 stations at a total cost of £11,000,000. This was was broken down as follows:

- Cost of ticket issuing and barrier control (including all installations and architectural work at 'easy' stations). £8,000,000
- Additional architectural work at 'difficult' stations (about 50 stations where full system 'C' was justified) £2,000,000
- Architectural work at about 20 stations where a special variation on System 'C' would be needed. £1,000,000

Total £11,000,000

The financial effect of going ahead with the scheme was likely to be an increased annual operating cost of £1,840,000 (which included additional staff costs). For this expenditure to be justified the average increase in station receipts would have had to have been at least 3½ per cent, to be achieved by reduction in ticketless and fraudulant travel. In this connection LT looked with optimism at the results of the Leicester Square experimental tripod manned barrier (which had yielded a 15 per cent increase in station receipts over a 25 week test period). LT realized that this may not have been typical and that it would be better to assume a lower figure for the system as a whole until actual results could be ascertained: an 8 per cent improvement was decided upon as the benchmark for success.

On the basis of this submission the GLC authorized LT to proceed with System 'C' in accordance with the strategy set out in the LT submission. This appears to have authorized the 'final' system described earlier, but operating the 'interim' system until most stations had been gated.

However the GLC authority came with two caveats. One was that the results achieved at the early installations would be reported back to the council as soon as practicable and the second was that costs should not be incurred at any station where it appeared unlikely that there should be a positive return. Inevitably this could be problematic where any networkwide initiative were introduced where the network benefits could be undermined by the need to avoid possible losses at a small number of individual sites. We do not know how this would have been dealt with as matters did not progress that far.

Death of System 'C'

The gating programme proceeded painfully slowly but by March 1976 LT felt able to demonstrate the preliminary financial implications of System 'C' to the GLC. By this time they had made the following progress :

- installation was complete at 22 stations;
- site work 80-90 per cent complete at 8 stations (ready for commissioning in April);
- contracts were let for structural work at 4 further stations;
- planning and design was complete, and layout plans approved, for 12 stations;
- preliminary design work had been carried out at 4 stations.

The GLC noted that the expenditure authorized for just the 1974/5 parts of the programme was £1,400,000, and so far £1,376,000 had been spent or committed and the work was far from complete—costs, especially labour and materials, had risen by as much as 35 per cent. Whilst explaining the delay in getting the information, this did not augur well for any systemwide installation programme, and the GLC was concerned at the implications of some of the explanations given. There was a marked lack of enthusiasm for further installations and this was not helped by LT admitting that measuring the benefits accurately was very difficult.

So far as LT was able to identify the financial improvements made so far, there were only 17 stations where the equipment had been in use long enough to offer meaningful data. The headline total was that for £400,000 of capital costs, annual operating costs had risen by £61,500, receipts had improved by £152,500 and thus annual net savings of £91,000 were being achieved. However, this amounted to only a 4½ per cent improvement, woefully short of the 8 per cent expected and we must consider that these were amongst the stations felt most likely to yield a return. Moreover, the spread of results was curiously high, ranging from 9.1 per cent at Colindale to 2.2 per cent at Arnos Grove. At only four stations did the net revenue improvement exceed £7000 on an annual basis. Even LT thought the results rather disappointing.

LT explained how difficult it was even to measure the improvement. For example the obvious increase in receipts at modified stations would, amongst other things, have to allow for the reduction of receipts paid in elsewhere (such as excess fares). Some types of fraud would have transferred to other stations nearby (or had adapted and had yet to manifest itself).

A factor not adequately taken into account when proposing System 'C' was the impact of the prevailing staff shortage. System 'C' required separate ticket collectors to operate the tripod 'inwards' barriers to those required at the 'conventional' outwards barriers. During a time of acute staff shortage conflicts arose as to which barrier to staff and which one to leave closed (or left open, but unattended). In practice it seems that when staff were not available there was a tendency to retain the ticket collector at the tripod barrier only (thus maintaining some sort of ticket control), with consequential clashes in passenger flows. At any rate this did nothing to improve flows and increased the annoyance already detectable in having to use the unpopular tripod gates. At other stations it was essential for flow reasons to have the exit ticket barriers available at all times, so anyone entering the system with the wrong ticket (or no ticket) just went through that gate when it was unstaffed.

The outcome of discovering that the case for System 'C' was at best marginal was LT suggesting that the network-wide programme should be paused after the work in hand or committed had been completed. Another factor in this was that agreement had still not been reached with BR about their proposals for introducing AFC in London and this would inevitably have an impact on how matters ought to be taken forward. Two other factors might be relevant (neither in the LT submission). First it is inconceivable LT would attempt to pursue a policy with which the GLC officers disagreed (the latter being much closer to their political masters were more astute at knowing what was likely to be acceptable to the Council and its committees). Secondly, it was slowly becoming obvious that new technologies were becoming available and that rethinking the whole idea of automatic ticketing might be sensible, and we shall pursue this in due course. Indeed £49.5 million was inserted into the following year's long term budget for AFC 'future system'.

The GLC concurred with this 'pause' but in reality System 'C' was dead and the best that could be hoped for in the immediate future was some minor tweaks and a few tests. At some stations, as a temporary measure, only the most basic coding was being put onto tickets, saying no more than 'this is a ticket' and to reduce real or imagined fraud an effort was made to make the gates respond only to tickets actually issued at the same station. Whether all the stations were adjusted this way I do not know, but I believe the first two were South Kensington and Hyde Park Corner. This introduced the faff of having to produce pre-encoded tickets which it had been hoped to avoid until the final iteration of System 'C' had been eventually introduced. It was then found certain enterprising regulars were entering their usual stations using the same ticket each day. This was countered by introducing an arrangement that stripped the code from any ticket that had been inserted into (and accepted as valid by) an automatic gate, thus preventing re-use (this was first tried at one of the two stations just mentioned, in 1977).

One reason for not using the main exit slot on the gates was that the System 'C' part of the transporter would have had to be used and this required the use of 2¾-inch tickets which was not a problem for tickets issued by machine but differed from the standard card-stock ticket issued through ticket offices which were only 2¼-inch long. In the early stages of System 'C' installation card stock would have to be used, and dated in a traditional dating press, and the racks only accommodated tickets of the shorter length. These were printed as required by British Rail at its Crewe ticket printing works at the rate of 60 million a year and a magnetic 'splurge' code was applied there before despatch. The Crewe machines could not print the longer tickets. Normally four of Crewe's 40 ticket printing machines were used for London Transport work, with four more available for large jobs such as a fares change. It was eventually agreed that BR would obtain a special 'Hugin' press that could print 2¾-inch long tickets on a slightly thinner card and gradually yellow tickets intended for use in automatic gates were converted to the longer card and corresponding ticket offices had some special ticket racks fitted. The odd position arose where on 2-part return stock the forward portion was longer than the return portion. However so far as I have been able to tell the extra section of the ticket transports were never used.

Beyond all this, the System 'C' aspiration was formally abandoned from 1977 and although the existing equipment was left in place all development work gradually turned to the 'future system' to be investigated shortly.

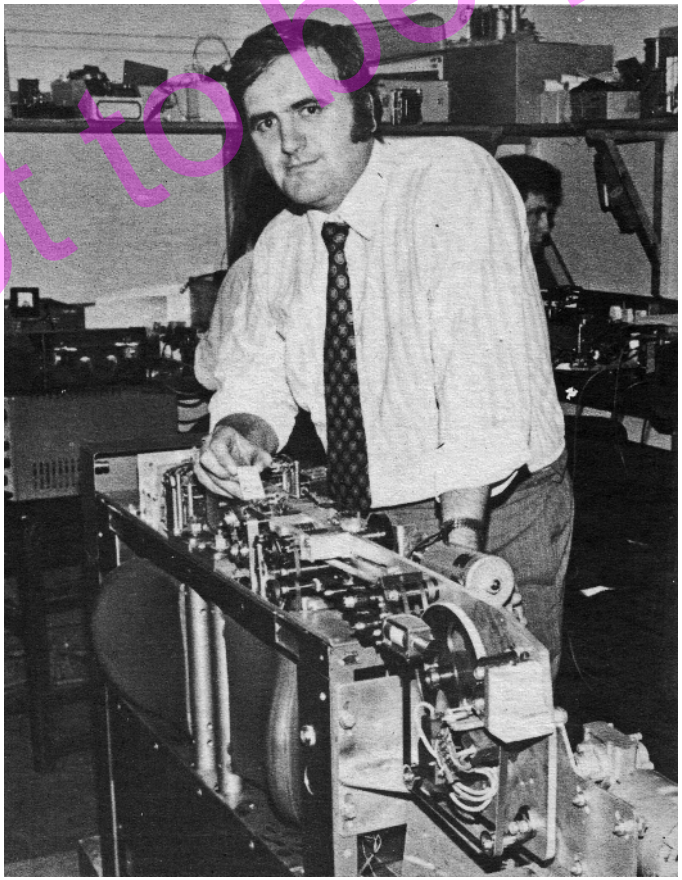
Chapter 14
A New Automatic Barrier for System 'C'

For System 'C' to work it was necessary for the ticket transport mechanism not only to check the coding was valid on the pre-sold 'blank' ticket, but also to print the date and station of validation onto the face of the ticket. This alone required a complete rethink about the design and configuration of the ticket transport system. In addition, it was apparent that the existing design of gate (the Victoria Line style) was in many respects unsatisfactory. In particular it was far too bulky and whilst it could be deployed at the mainly new Victoria Line booking halls the size was going to be a huge constraint if attempts were made for its widespread use at many existing sites, even if only on the Way In. It is true there were the more space-efficient turnstile types used at Euston and Warren Street but they slowed down the flow more and it was hoped in any case to use only one type of gate. In short, this called for an entirely new design to meet the needs of System 'C'..

Work therefore began in 1972 on the design on a new 'slimline' gate, the work being funded from the £234,000 savings thought achievable from the GLC authorization made in 1972, described earlier. The patent for the resulting gate explained that an adjacent pair of the Victoria Line 4-door gates occupied 80 inches of space while a pair of the slimline gates occupied only 70 inches; this was achieved by a complete redesign of the operating mechanism so that intermediate stanchions carried gate paddles on both sides, so enabling only one intermediate stanchion being used instead of two. The new gate leaves were lightweight red-coloured moulded paddles instead of the earlier padded frames. These were not very high in order to allow luggage to pass underneath yet fold back into the stanchion allowing sufficient height in the casing above for part of the ticket transport mechanism. Arguably this reduced the resistance to a certain type of customer who could get under or climb over the paddles, but this was hard to do without drawing attention and was not thought to represent a substantial cause of loss.

Examples from July 1974 of what appear to be test tickets for System 'C', blank on left and after validation in gate, right. This is from very poor original but no other example known. The added information includes station name and date..

The gate design was flexible and allowed gates to have either two or four paddles, operate in closed mode or open mode, and be uni-directional or bi-directional (thus being fairly future proof). For the immediate future only one-directional gates were planned and these lacked the ticket transport mechanisms and ticket slots needed for reversible operation.



A picture from July 1974 showing an experimental System 'C' gate under development by LT. This shows the rotary transport at front in which the code is checked, and the reject slot immediately above. The printer unit lies to its rear (above the paddles) and returns a printed ticket near where man's hand looks as though it is holding one. On this gate the transport looks as though it is mounted centrally along the stanchion but it is actually offset to the left hand side.

The arrangements of ticket slots was novel, for there were two 'exit' slots, a necessity created by the length of the ticket transport system, which was very long. In normal operation a ticket would require validation in the printer unit. The idea was that the gate would open as soon as the coding was proved correct, lighting discrete green lights towards the exit end inviting the passenger forward. The short delay whilst the ticket was being validated meant the best place for the ticket slot was some way into the gate near the paddle mountings, the arrival of the ticket hopefully coinciding with the passenger's hand as they went though. However, if the ticket was defective, it did not need validation and if it appeared in the 'normal' slot it would be awkward for the passenger to retrieve. A second 'forward' slot was therefor provided above the transporter, near the front of the gate, intended only for defective tickets. Adjacent back-illuminated labels would light up by whichever slot the ticket had emerged. For some reason these slots were nearly invisible when not in use, being covered by

Represented here is gleaming example of a prototype 4-paddle gate, probably still on workshop test. Visible is the ticket entry slot and slightly further back a ticket ejected from the nearest exit slot with adjacent label lit up. The purpose of white inset arrangement further along is not known and did not appear on production gates. Visible along near panel is recess where paddles could be fitted if stanchion was used in intermediate position. .

Above left is one of the production slimline gates developed for System 'C', this one installed at Earls Court in February 1975. Similar to the prototypes, this was built by Tiltman & Langley of Redhill and then assembled by London Transport before being taken to site.

Above right is an example of the pedal-released tripod gate installed at manned inward barriers such that the barrier was not released until the ticket examiner was satisfied the ticket being shown was correct. These were very unpopular and slowed down flows of passengers. The view here is of the 1972 experimental installation at Seven Sisters.

a flap, spring loaded closed unless a ticket was being presented. This may have been to discourage passengers from gazing at one empty slot when the ticket had appeared at the other.

For the interim System 'C' system the printer and validation unit was not used and it was arranged that during what it was expected to be the installation phase, perhaps up to two or three years, once the code check had been done all tickets would be ejected from the nearest exit flap and it is to be doubted passengers knew there was a second one further along. The first gate in public use is reputed to have been installed at High Street Kensington during 1974.

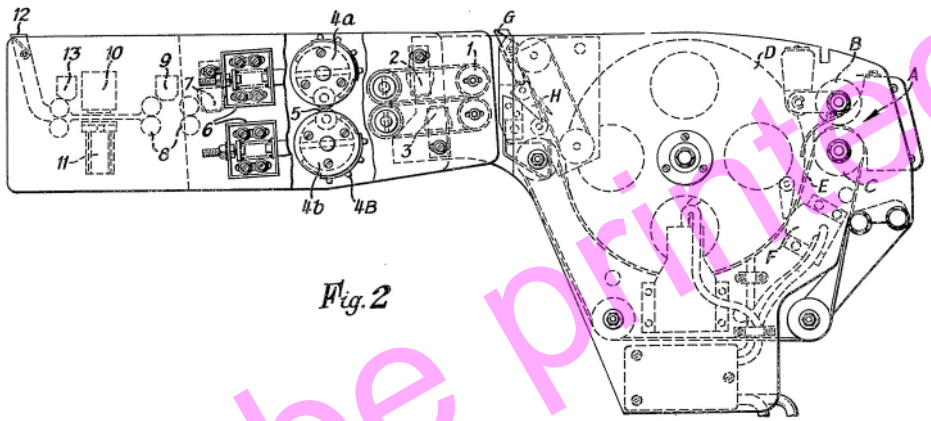


Fig.2

This shows the slimline ticket transport unit with ticket entry slot (A) at right hand end. Ticket grasped between wheel (D) and band (E) and read by reading head (F). At (H) ticket is either rejected at slot G or conveyed via the left hand section to printing and dating blocks and then ejected at slot (12).

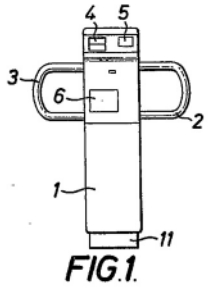


FIG.1.

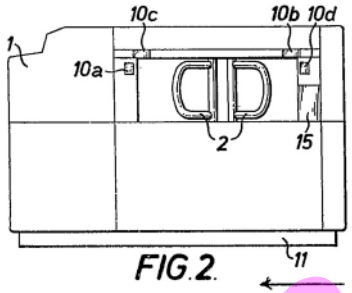


FIG.2.

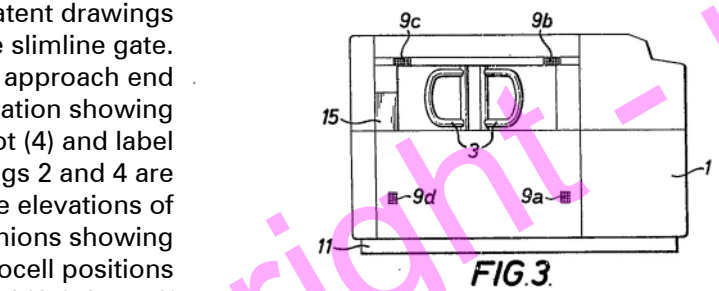


FIG.3.

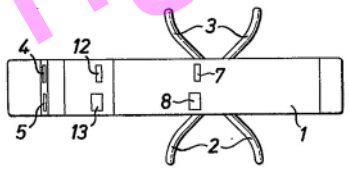


FIG.4.

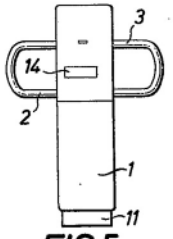


FIG.5.

Shown here are some of the patent drawings for the slimline gate. Fig 1 is approach end elevation showing entry slot (4) and label (5). Figs 2 and 4 are side elevations of stanchions showing photocell positions and (15) the red/ green stop/proceed indications. Fig 4 is top plan showing entry slot (4), reject slot (12) and normal ticket return slot (7). The gate unit (1) sits on floor mounted base (11).

The installations of slimline gates were all made using the 2-paddle version and, like the Victoria Line gates, the paddles were pneumatically controlled.

These slimline gates were installed at Hatton Cross. Just visible on interior side panels at rear of housing are what appear to be the indicator lamps (15 on patent drawing). It is not at all clear these were fitted to all the gates, nor do I recall them

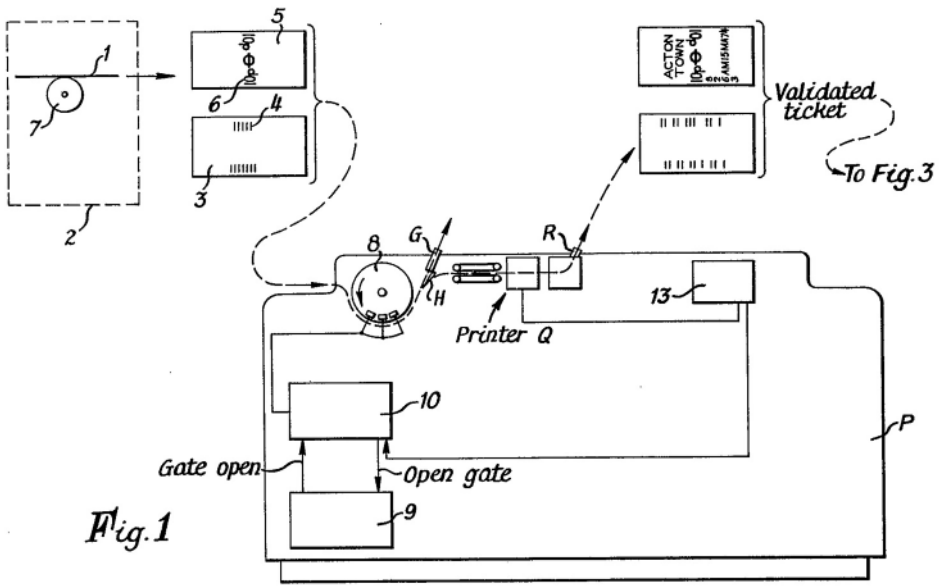


Fig.1

This is a drawing from another LT patent, supplementary to the main patents relating to gate and transporter mechanism. In essence this describes a possible mechanism (not part of System 'C'), whereby a priced but otherwise blank ticket might be read in a gate and not only validated by imprinting date, time and station of origin on the card but electronically adding this information to the oxide reverse of ticket by reading and wiping starting code and re-encoding ticket including the additional information. This may have been tested in workshop conditions, but not (I believe) in service. There would have been no point in doing this unless exit gates were in use and may have been part of the 'future system' ideas. The drawing is useful in showing representations of both unvalidated and validated tickets.

One of the last System 'C' gateline installations in early 1976 at Leytonstone.

At the stations equipped with the new slimline gates, installation work took place over about a month and largely involved provision of power, cabling and control equipment. Installing the gates was done last and was often an overnight job. The plinths were fixed to the floor and connected to the cabling then the gate stanchions dropped on top.

Chapter 15
A New AFC System For London

Something New Required

Even as early as 1976 a degree of disenchantment was evident with the AFC equipment installed and its ability to solve more problems than it caused. Capital budgets began to appear with money allocated to 'AFC - New System', with development money until 1980 and then a large expenditure on installation. But this was just financial planning. There was then no technical system available and no authority to spend that kind of money. LT described the future concept as 'tentative' and thought it might cost about £46m to install, partly owing to the structural alterations required at many stations, though within a year this had risen to £51m once development work had been refined.

While System 'C' was beginning to unravel, other moves were already in hand. As long previously as 1974 some kind of successor system was being contemplated, action being in part precipitated by the proposed development by British Rail of its own AFC system in the London area; whatever either organization came up with would have to be compatible with the ticketing system of the other owing to the huge exchange of traffic between the organizations (the BR proposals are discussed in Appendix 4). In January 1975, London Transport signed a contract with Plessey to examine the opportunity for a successor to System 'C', taking into account British Rail's own development work. This detailed examination was available in October 1976 but it was not until July 1977 that LT was ready to present something to an already-sceptical Greater London Council. While the analysis was led by Plessey a new LT project was established to oversee the work.

A Proposed New System

It can be little surprise that the proposals effectively required LT to start again with seeking a coherent solution to the various issues that had been identified, many of them not new. The challenge was that (to use 1976 figures) 540 million journeys were being undertaken that year, generating £122 million in fares revenue but requiring employment of about 3000 staff to manage the revenue collection and protection system at a cost of £14 million (though about half of this staff time was spent on other station duties that might have to be retained). After a substantial amount of testing and investigation it was felt about £6.5 million of revenue was lost each year through fraud (about 5 per cent) and attempts to reduce this was creating the potential for delay to, and conflict with, honest passengers. Attempts to deal with this with earlier systems had foundered on technical complexity and reliability, only equipping a small proportion of the system and the need to accommodate British Rail tickets that accounted for about 15 per cent of journeys. Attempts had been made to reduce tickets for through journeys (perhaps inconveniencing users) but there was now pressure to improve the convenience of through-booking offers, and this had to be allowed for in any future development. Costs had been incurred without the benefits possible from large scale implementation.

The 1976 study built on what was already known and had taken place with the co-operation of British Rail which was developing its own system (its requirements were different to those of LT). It was now felt that at least from a technical point of view it was possible to devise a system where the tickets of either operator would work on both networks. BR was expecting to undertake live trials on the Twickenham route in 1978.

The LT proposal was to introduce full automation at every station using both exit and entry gates for all ticket types; it was recognized that there might be a few stations where exceptional architectural costs would make this difficult, but that 'the system could tolerate two or three stations where entry or exit would always be manually controlled' (in addition to stations where short term works might require the gates to be temporarily out of use). The

type of gate was not gone into at this stage but it was felt the new slimline gate, already installed at 50 stations, would have a role. It was accepted that many gates would need to be reversible to handle peak flows.

Further automation of ticket issuing was expected by substantial increase in the number of ticket machines, but it was planned only to reduce manual ticket selling proportionately, and not to withdraw it. The new machines would deal with higher value fares and change giving was now regarded as crucial to its success. New ticket office equipment was expected to automate as much of the accounting as possible (manual accounting was time consuming and not error free) and to introduce complete personal accountability for all transactions. It was a bone of contention that in many ticket offices the consequences of an error made by one clerk was difficult to pin down and any losses had to be borne by all of them. It was noted that some of the existing issuing equipment was quite old and needed replacing anyway.

The actual tickets would continue to be of the existing width (used with the existing type of gate), and tickets other than singles and returns would need changing to the smaller format. British Rail were happy to use this format in their gates (and their experiments were to use the same type of ticket). However BR wanted to retain a larger format for their seasons and were looking at a design of gate with two ticket slots, one of each size. At this stage it was not resolved what through seasons from BR to LT would look like but it was possible passengers might have a separate ticket for each part of the journey (even though sold as a single transaction).

It was understood even at this early stage that much of the processing would have to be done at station level but there would be tremendous advantages in having a central supervisory computer (by now small commercial computers were becoming available). This was primarily to collect and aggregate management and accounting information and compile statistics.

A particular objective was extremely high reliability as it was recognized that without it existing staff could not be redeployed. Assuming reliability was achieved it was thought £2.5 million staff savings were achievable. The project team was mindful of experience in Paris where very heavy staff reductions were made following major automation and it was quickly found crime and vandalism increased markedly, requiring increasing the number of police.

LT estimated the total scheme cost as £55 million, of which the largest component was station rebuilding. LT considered £10 million would have to be spend on new equipment anyway, so the net cost was only £45 million, but the GLC officers explained to those having to approve the expenditure that it was the gross figure that had to be justified.

The net cost breakdown was as follows (gross cost breakdown unknown):

Item	**Cost (£ million)**
Gates and associated equipment	4.0
Passenger and ticket office machines (all)	10.4
Cabling and power supplies	6.5
Computer hardware and software	2.5
Installation	1.4
Maintenance start up and spares	2.2
Building construction and alterations	15.4
Miscellaneous, land, project management, BR compatibility	2.6
TOTAL	**45.0**

The savings in staff, fraud and other avoided costs came to £6.5 million annually and that allowing for the usual discounted cash flow methodology a payback period of ten years appeared likely. Some of the assumptions much affected the outcome, for example the actual amount of fraud reduction, and this and some other factors meant the proposal was by no means clear cut. At this stage funding of £100,000 was available for the project team to carry on its work, but no further authority was given at this stage.

The GLC commentary on the LT submission was by no means antagonistic but showed evidence of suspicion (based on bitter experience) that LT's enthusiasm for a scheme did not always mean it was thought-through and robust. Weak points appeared to be the compatibility with BR proposals and

the fact LT sought to justify this high expenditure primarily on the need to combat fraud: the GLC was suspicious that much of the benefit could be achieved without this enormous investment. So frustrated were the officers they actually began making suggestions of their own.

Matters rumbled on into 1978 when LT made a more complete submission to proceed with the new-generation system having first sought to reassure the GLC that it was not possible to do so 'at low cost'. Before any authority was given LT was required to re-examine all options for making the ticket system more efficient and reducing fraud. In June 1978 LT responded with a detailed analysis of all options for moving forward, including what GLC officer referred to as a range of 'cheap' alternatives. Finally the GLC was persuaded that whilst LT 'cannot guarantee success [officers considered the proposed] AFC offered the only economic means of making inroads into the fraud problem'. They still had concerns about BR compatibility, presumably aware of the huge stumbling block it had been hitherto on a system with so much interworking.

In making the LT case, the former arguments were restated but additional advantages for the new system were now claimed. One of the more important was the ability to introduce (if required) stored fare ticketing where journeys were paid for as they were made from a credit held on the ticket. Alternatively the purchase of tickets in bulk would be possible, each validated for travel the first time it was presented to a gate. Reassurance was given that the new system was compatible with zonal or flat fares, if required. The new station layouts would also save passengers time—550 million seconds a year was claimed. All the low cost options were re-examined, restated and demolished by LT's carefully crafted responses. One was the idea of penalty fares (not then used by LT) as it was doubted suitable parliamentary powers could be obtained.

One low cost idea, which appealed to the GLC officers, was for Authority to Travel (ATT) machines to be introduced that could be turned on when a station ticket office was closed. The idea was to issue a special 10p ATT 'ticket' that 'proved' where a passenger started their journey, improving the chance of the correct fare being requested and accounted for on arrival at destination. LT had hoped to introduce these during 1976-7 and *LT News* records that by April 1977 some 32 stations had already had machines installed and that 90 further machines were waiting to go in. However they had not been commissioned and for some reason difficulties (presumably with trades unions) had halted implementation. Thirteen of these red painted machines were brought into service from 4th December 1977 on a 3-month experimental basis. After that we hear no more of them and it appears no more were commissioned and that those installed were removed and stored.

The 1978 proposal had some interesting detail in it. The following points might be of interest and come from the list of assets that would be displaced.

186 rapid printers purchased 1938-48
78 rapid printers dated 1953
38 rapid printers purchased 1963
103 mini printers purchased 1938-48
666 ticket machines purchased 1937-46

The accompanying memorandum pointed out quite a lot of this equipment was life-expired and would need replacing anyway.

The GLC remained suspicious but after further pleading, LT was permitted to go out to tender with future expenditure restricted without further submissions. In the meantime, in November 1978, an LT project team was established under Roger Webber (project manager) with Bernard Sharp (engineering), Colin Docwra (operating), John Gardner (systems), Tony Windmill (building design) and Douglas Allaway (revenue control). The tender was for Stage 1 which was the development of prototype equipment, for which £10 million was allocated with installation complete by December 1980. This facilitated notional costs of the complete scheme to be assessed by contractors and unfortunately it was apparent the complete installation would cost a great deal more than expected. The original estimate was for £55 million at July 1977 prices, but readers might recall this was a time of rampant inflation and at February 1979 prices, exactly the same estimate was re-costed at £68.9 million (this was due to inflation alone). The new estimate from the

appointed contractor had come in at £86.8 million, at February 1979 prices, a real increase of over a quarter. It was suggested systemwide installation (requiring major alterations to stations) could be complete in 1985.

The tendering exercise was complicated by the two-stage approach. The development work required in Stage 1 inevitably had to consider how the final system would be implemented, whilst the success of the final system hinged on the robustness of the equipment developed during Stage 1 and the planning and development work. This made it impractical to appoint different contractors for each stage and whoever won the contract for Stage 1 would be expected to deliver Stage 2. To try and ensure value for money would be achieved, as much of the equipment and installation work would be competitively subcontracted.

EMI and GEC made a joint bid for £75 million with Stage 2 delivered over 30 months. Plessey and Marubeni (a Japanese firm) bid £55 million, ICL and CGE Alsthom bid £64 million and Westinghouse Cubic bid £47 million and won the work. The ICL and CGE Alsthom (a French company) revised their bid to £46.5 million during the bidding, but this was not accepted, even though it was now just smaller than Westinghouse Cubic. This caused a certain amount of excitement within both the GLC and the LT Passengers' Committee but LT stuck to its guns.

Unfortunately the tender award now coincided with a particularly difficult period for obtaining capital funding and progress was painfully slow. The 1980 annual report noted:

A typical UTS ticket office comprising ticket issuing windows, assistance window (out of view on left on paid side of gateline) a multi-fare ticket machine (MFM) and, nearest camera, a fewfare machine (FFM).

> Development of the proposed comprehensive automatic fare collection system encountered some delays, and the reduced level of capital funds means that rapid progress towards full implementation is now unlikely to be possible in the short term. A pilot installation, upon which further development can be based, is now planned for 1981.

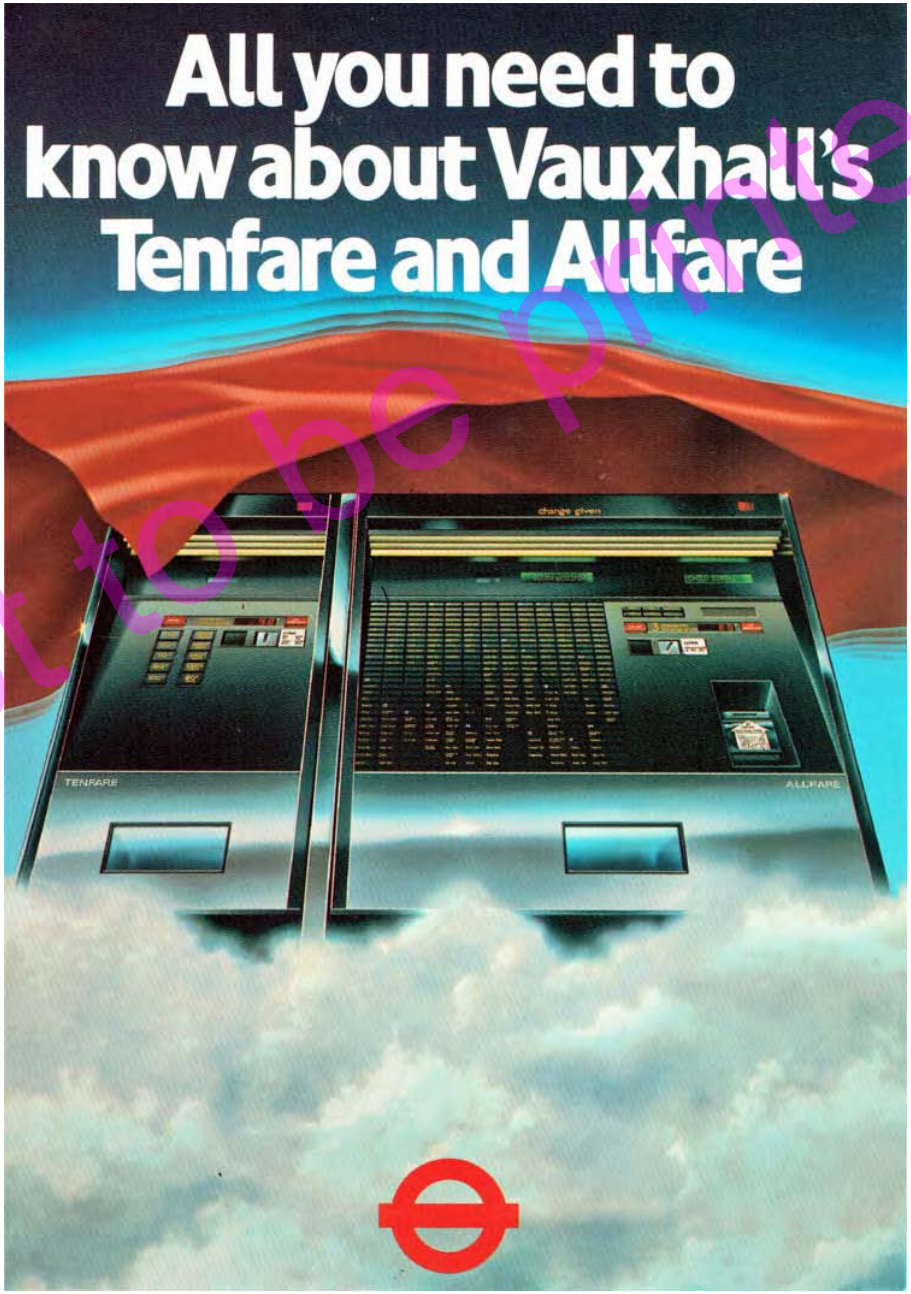
The Prototype Equipment

At last, prototype equipment was delivered to the project office near Victoria in 1981 and testing could begin. The concept involved the following elements, several of which represented significant changes to the earlier thinking:

1. The bulk of ordinary tickets to be sold by machines that could be serviced from within the ticket office, as at Hammersmith in 1966 and Ealing Common before that. There would be no free-standing machines.
2. Since the majority of sales were for a small range of tickets, relatively small machines (that became known as ten-fare machines) would handle these sales, one machine offering up to ten ticket types selected by large push button. There would also be at least one, much larger, ma-chine that could sell all ticket types, also selected from a large array of push buttons; this became known as the multi-fare machine. All ma-chines would give change, the change reservoir automatically re-floating from cash taken. The multi-fare machines would also take notes.
3. Seasons and less frequently sold tickets (eg for British Rail destinations) would be sold from a ticket window.
4. No 'value' stock tickets would be necessary and every ticket type would be sold from one machine and printed at time of sale. In turn, this allowed virtually all accounting (a major chore) to be carried out automatically.

5. All tickets would be larger than previously and it was decided to use credit card sized tickets (the same size as British Rail was introducing but, except for seasons, without any pre-printed information).
6. On completion of the project, every station would be fully gated. Excess fares (of which it was expected there would be very few) would be paid at an 'assistance' window at the ticket office, the window being on the 'paid' side of the barriers. The clerk would deal with the trans-action and issue an excess ticket that would work the gates (as on the original Victoria Line system). The clerk could deal with any query where a ticket would not operate the gates and if necessary could open a gate automatically.
7. To allow for all the new equipment and the necessary configuration of assistance windows and automatic machine servicing, major changes to station layouts would be required. It was decided, in addition, to make ticket offices secure self-contained units with a messroom and toilet in each, vastly reducing the need for clerks to go in and out and making the suites very difficult to break into or steal cash from. For very practical reasons this meant ticket offices had to be located along the sides of ticket offices rather than being free-standing. This was all going to be very expensive.

At left is the prototype equipment installed at Vauxhall and at right is one of the many leaflets produced to explain it.



The prototype equipment did what was expected of it and with some refinements it was decided to install a complete set of equipment, including new style ticket office and gates, at a station to see how it all worked in practice. While potential booking hall layouts were being considered the prototype equipment was subjected to extensive testing at the project office, resulting in some modifications.

The station selected for the trial was Vauxhall, not far from the project office in Gillingham Street and at that time not especially busy. The station works and equipment installation took place during the summer of 1982, the new kit being on the opposite side of the ticket hall from the existing ticket office. Two ten-fare machines and one multi-fare were installed and a new ticket office with two main windows and an assistance window. Each window had one of the new ticket office machines that also issued tickets of the new size. Four automatic gates (two each way) were installed and the new equipment came into use on Sunday 31st October. The trial was expected to last about nine months (it actually finished in July 1983).

By now, the earlier plan to use at least some of the existing ticket gates had been abandoned and an entirely new design had been arrived at. This was partly needed because of the larger tickets now proposed, requiring a proportionate increase in width to accommodate the ticket transporter. There were also sound ergonomic reasons for a better design than any of the existing barriers. The new design involved a single pair of gate paddles on unidirectional gates and two pairs on reversible gates. The paddles were (as on earlier designs) powered by compressed air motors as a compressed air supply was available at all stations (BR had no such supply and had to devise a gate with electric motors, which were much less brisk in operation). The gate logic differed from earlier LT designs by requiring a passenger to remove the ticket from the exit slot before the gate actually opened, much reducing the risk of somebody leaving their ticket behind. The disadvantage was some passengers unfamiliar with the system were puzzled by the gate not opening, not realizing they had to remove the ticket first.

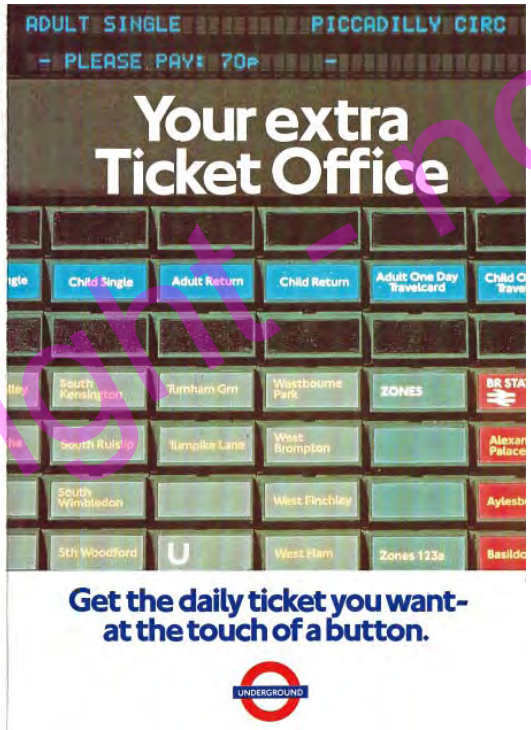
The ticket transporters were subject to rigorous testing before delivery to LT, some 2-3 million operations being undertaken to prove their robustness. The location of the entry and exit slots was crucial to high passenger throughput and the final design allowed an experienced commuter to insert ticket and retrieve it (releasing the gate) without breaking step. Unlike the earlier gates the tickets had to be inserted face up (ie code side down) although either end could be inserted first. This was because the code had to be read and rewritten and there was only space for the read/write heads on one side. Passengers intuitively inserted tickets face up but those inserting them upside down were perplexed (from 1990 they were marked This Side Up). The ticket coding was entirely different from anything used before and had a density of 50 bits per inch (the Victoria Line system was just 15). BR, with its more complicated network, had opted for the even higher density of 100 bits per inch and it had been decided that the magnetic stripe would be divided into LT and BR zones and that for through journeys the necessary information for each leg of the journey would

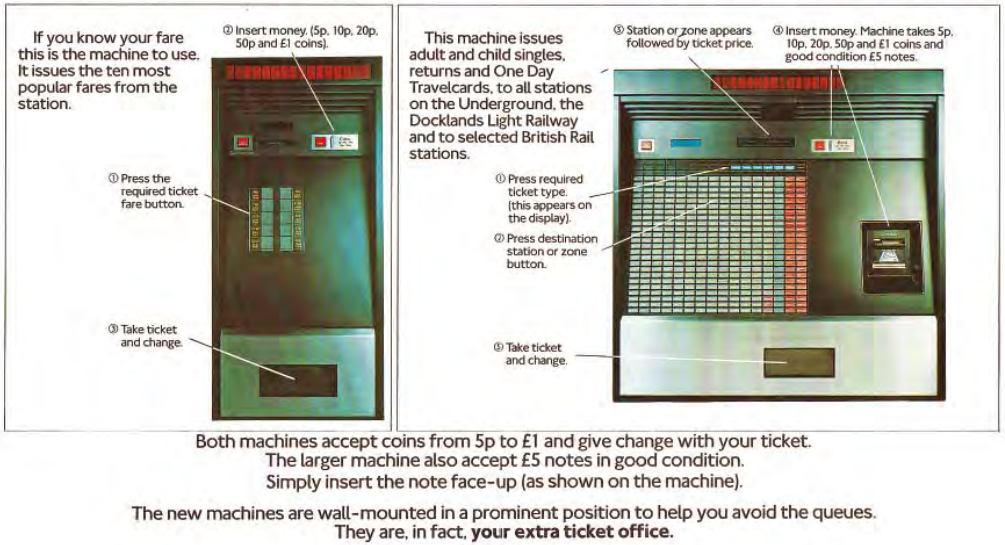
Final designs on test at WCL offices in Merstham, 1985.

be encoded into the respective zones. That way each organization had only to concern itself with checking its own part of the ticket.

The trial equipment was supervised by a station computer, installed first at the team's offices and then moved to Vauxhall. This (and subsequent) computers could control up to ten gates and was loaded with all the fares information, ticket validities and so on. The computer was actually two Hewlett Packard HP100 minicomputers but with only one on-line; the Vauxhall equipment relied on a magnetic disk memory but the computers used on the systemwide installation used solid state random access memory. The station computer was connected to a central computer at LT's existing computer centre at Newman Street. Apart from collecting statistical information centrally, it had the capability of uploading revised fares tables to the station computers and distributing operating information so that, for example, if there was a coding error at one station then the processing equipment at other stations could allow for it. Only part of this capability was needed with only Vauxhall equipped during the experiment.

Ticket design relied on a dot-matrix thermal type printer printing the necessary information onto blank ticket roll, the printed ticket being sliced off the end of the roll and dropped in front of the booking clerk. The ticket roll was yellow and was not quite blank as it was overprinted on the face, near the top, by a notice in black stating it was issued subject to conditions. The reverse was blank and covered entirely by magnetic material. All tickets, including period tickets, were issued this way. The printing was distributed over the whole of the face of the ticket, usually with the name VAUXHALL





in the top left (where valid to a station beyond the central London zonal boundary the 'station name' was replaced by WEST END ZONE. The design accommodated a single horizontal line near the top if they were period tickets, whilst one day tickets had a second horizontal line along the middle. Tickets not valid for Underground travel bore three lines.

While the trial was in progress it was realized that the cost of installing gates at every station appeared not to be justified by the likely saving in revenue. The strategy was therefore refined so that all central London stations would be gated but not those outside, where traditional manned barriers would be retained until such time as automatic gates were provided (gate positions were planned and air mains and cable trunking was installed where convenient to minimize work required later). The thinking was that the majority of journeys started or ended in central London so a ticket would be automatically checked at least once. As a further deterrent to irregular travel it was intended to increase on-journey ticket examination outside the central area by mobile revenue protection staff.

The Vauxhall trial was considered successful from both a technical and operational point of view and had also (it was considered) been found favourable by passengers, who had been content to switch to buying more tickets than previously from the machines. Importantly, station receipts had increased, justifying expectations. To the extent that there were shortcomings, these were taken account of in the emerging specification for systemwide introduction. The trial was carefully written up and recommendations made for improvements (eg placing the ticket office machine ticket roll on top of the machine so it was obvious when it was going to run out, rather than tucking it neatly away).

Chapter 16
Underground Ticketing System (UTS)

Systemwide Introduction

As a result of the Vauxhall trial, London Transport refined its specification for systemwide introduction of an AFC system, which had by now become known as the Underground Ticketing System (or UTS, for short). The GLC reviewed the results of the trial and accepted London Transport's proposals to introduce the first phase of UTS. This comprised reconstruction of all ticket offices and installation of the new ticket machines at all stations. A second phase was expected to follow, comprising the introduction of central area gates.

While all this was going on, we find the GLC at loggerheads with the government, leading to the abolition of that local authority with effect from 29th June 1984. In consequence, control of London Transport was transferred to the Secretary of State for Transport from the same date, the organization being renamed London Regional Transport. The legislation made provision for subsidiaries to be established and from 1st April 1985 the Underground staff and assets were transferred to a subsidiary called London Underground Ltd and it will be convenient to refer to the organization as London Underground from here. The Department for Transport fortunately agreed with the adoption of automatic ticketing and as they were now the paymasters also formally approved the first phase for £105m and gave provisional approval for the second phase for a further £30m. It was planned to have the system operational in 1988. It will be noted that costs had again increased, but a substantial element of this was inflation.

During 1987 work was in hand at over 100 stations. The work volume was enormous and very varied. At some stations existing ticket offices were enlarged, often requiring temporary ticket offices to be provided. At other stations new ticket offices were provided on new sites. In addition to ticket

On left is shown a pair of typical fewfare machines illustrating the simple push button arrangement. The machine self-floated its change and indicated when change could be given. There were later found some problems when spurious coins were inserted and transaction cancelled, as good coins were returned. A software change fixed this.

Below is one of the several leaflets produced in large quantities to explain how the new equipment worked.

offices it was also necessary to provide a station computer room (SCR) as the machines and accounting systems at each station were linked to the computer, which held all the fares and accounting data. These were linked to a network control centre at 55 Broadway and a new computer centre at Baker Street. The SCR did not have to be part of the ticket office suite, but providing space for one anywhere was a challenge at some stations. Where possible UTS works were co-ordinated with station refurbishment programmes and managed on site as a single project.

Hammersmith (Metropolitan) station was completed early in order to get experience with the proposed production equipment, the ticket office and automatic machines (and the UTS-style tickets) coming into service on 20th April 1987. The equipment operated as expected. The first of the 'production' ticket offices was at Amersham, which opened on 6th July. In many cases (as here) clutches of nearby stations were adapted in groups, gradually moving along the line.

By the end of March 1988, 120 stations had been equipped with the new ticket offices and passenger operated machines the first automatic gates began to be introduced, the first station being Chancery Lane on 30th. These again were an 'advanced' installation to gain experience, the main period of commissioning starting on 10th June at Warren Street. The final station to receive its UTS ticket office and associated ticket issuing machines was Covent Garden (a very difficult site) on 1st July 1989, the gates followed on 20th November. The last station to receive gates as part of this programme was Gloucester Road on 14th January 1990. There were two stragglers; Kings Cross Thameslink (a BR station) was not gated until 29th July 1991, and Monument (where other works were in hand) was not gated until 25th November 1991. As at Vauxhall the gates were all pneumatic and usually air mains had already been installed in the floor during the main station works, so installing gates was relatively easy.

A staff training facility opened in a disused entrance at White City station in March 1987 using the experimental equipment from Vauxhall. This included a ticket office with a ticket issuing machine and examples of the passenger operated machines. The station computer was also installed, and a link to the network computer, but the setup did not, at least at first, include gates.

This is a typical UTS gateline installed in an old and inconvenient layout but shows a mix of one-way and reversible gates, and 'heritage' treatment of ticket office exterior. The gates had now acquired stickers pointing out ticket had to be inserted right way up.

Technology

At station level all equipment doing a similar job was so far as possible standardized, for example the matrix ticket printer used in the ticket office machine was the same as that used for the passenger operated machines. This much-simplified training, maintenance, spares holdings and so on. The printing units were required to print a ticket in under two seconds (a long time compared with the third of a second of a rapid printer) on either card ticket

roll or on pre-cut stock which for period tickets was impregnated with plastic to make it more durable.

The fewfare machines could issue eight popular tickets, selected by pressing a corresponding button. These only took cash but could normally give change. The multifare machines had to be easy to use and a large matrix of push buttons was felt the clearest way at the time. A separate push button was provided for every Underground station, with space for a further 48 buttons for selected BR destinations, a further 24 in case passengers wished to select zones, and spare positions were provided to allow for system expansion. This required a total of 384 buttons, each marked with a station name (or equivalent) and arranged in alphabetical order. Additional buttons allowed selection of ticket type, which excluded period tickets that had to be obtained from ticket office. Though looking formidable, familiarity was quick to achieve and these machines were quite simple in operation. In addition to giving change they incorporated a note-accepting module. The ticket office machine was actually two devices, one either side of the window. One was a combined keypad and display unit used to call up the required ticket and the other was the printing unit itself.

The gates were based on those developed for Vauxhall but to discourage people from vaulting or climbing over them the paddles were taller and a strategically-placed display panel on the balustrade, coupled with elimination of footholds, inconvenienced anyone trying to climb over.

The tickets had only a magnetic strip along the back, unlike the Vauxhall tickets that had an all-over magnetic coating. The coding comprised 192 data bits coded at 2.95 bits per millimetre, making the track length 65mm. The coding was as simple as possible given it needed to contain information such as date, ticket type, stations or zones of origin and, if required, destination, validity and so on. The ticket issuing equipment not only printed and encoded the tickets but read the code to ensure it was correct, cancelling and retaining a faulty ticket. The matrix printer could manage four lines of print.

The bank note handler at this time accepted only £5 notes and after validation could handle up to ten in escrow until the transaction had been completed satisfactorily, after which the notes were transferred to a secure vault.

All the station equipment was linked to a PDP11 station computer which supervised all the equipment and held crucial information such as each station's fare tables (although these were copied as necessary to the ticket issuing devices so they could continue to function as stand-alone units if the computer failed). Most stations had only one computer but a few had more; the maximum was three. The computers allowed stations to function autonomously. In particular they monitored equipment, supervised station accounts including reconciling cash. They also communicated with the system's central computer and stored data, such as fare tables downloaded from central computer, via 9600 baud modem using dedicated fibre-optic communication links (mainly spare capacity on the Underground's fairly new telephone system). The station computers were designed to provide local management information when requested.

Inner London stations communicated with the central computer at Baker Street typically by routes via both Embankment and Baker Street exchanges, the duplication providing great resilience, but outer stations usually only had a single route. At the Baker Street end further modems converted the signal back into electronic binary form and the lines were terminated on one of 20 concentrators, which were also PDP11 computers and which took some of the load off the main computers. The concentrators served a cluster of three DEC computers running programs on VAX architecture.

The main computers supervised the whole network of 300 station computers, 2200 ticket machines and other peripherals. The computers served three control rooms. First there was the Rail Operations Centre (called Operations Command Centre on opening in 1987), staffed by operating staff who monitored the status of station equipment and in the event of a possible problem could liaise with local managers or broadcast advice or information if a fault required to be known about across the network. It could also alter ticket acceptance rules where faulty equipment might have wrongly coded tickets somewhere. There was then an engineering report centre where technical faults were logged for attention and equipment monitored for less obvious faults. The nature of faults (including time to repair) was kept and analysed

for management purposes. There was then a Systems Report Centre where the computer systems themselves were monitored and controlled

Zoning

During 1980, London Transport was looking at the prospect of replacing its traditional pay-by-distance fares structure by a simplified zonal system, often used by continental metros. The problem with introducing such a system whilst keeping overall revenue broadly similar is that there are winners (who would pay less) and losers (who would pay more). The losers could number tens of thousands and the amount they had to pay extra could be appreciable. Politically, and perhaps morally, this made the transfer to a zonal system very difficult. There were ways of mitigating the down-side but this not only introduced unwanted complexity but would reduce overall revenue, so the problem appeared intractable.

However, in May 1981 a labour administration came into power at the GLC that wanted to see fares cut by at least a quarter. This provided what appeared to be a unique opportunity to introduce fares simplification since the worst that could happen to a journey affected by introducing zones would be they paid the same as before whilst the vast majority would enjoy the savings. In consequence, LT introduced two overlapping zones in central London, a City Zone and a West End Zone, and every ticket to a central London station was valid throughout the zone in which the station was located. Season Tickets to central London were printed with the name of the zone or zones to which valid rather than a particular station and could be used for unlimited travel within those zones. The scheme was immensely popular and successful and generated more travel than expected. The new zones came into use at the fares change on 4th October 1981 and the overall reduction in fares was about 31 per cent. It was this system that was in use when the Vauxhall experiment was in hand.

This is not the place to dwell on the ensuing legal battle that resulted, when Bromley Council took the GLC to court, and when the GLC's actions in subsidizing fares this way was found unlawful and searching questions were asked about the whole way LT went about funding its improvements. Suffice to say here that the immediate outcome was a decision to double the fares while the legal implications were gone into, and a fares change implement a fares increase averaging 91 per cent in March 1982, precipitating a huge loss of traffic and train service reductions.

Finally, it was felt that there was no justification for the (by now eye-watering) fares and in 1983 the GLC, LT and various teams of lawyers felt it was appropriate and within the scope of the court judgement to restore fares to a level about half way between the 1980 and 1981 levels

It might be mentioned here that in 1981 London bus fares were placed on a wholly zonal footing following some tentative moves in that direction with area bus passes. In the new scheme the bus zones in central London echoed the Underground's City and West End Zones and there were two further zones (Inner London and Outer London) beyond the central area and extending to the Greater London boundary. It was apparent that having another major fares reduction provided a second opportunity to introduce zoning on the Underground, and this time (with experience already gained) LT was much more bullish and introduced zones throughout the GLC area. The two existing central zones were combined to become Zone 1, and four concentric zones occupied the outer areas. Zone 2 coincided with the Inner London bus zone while three further Underground zones were created beyond that, occupying the area of the Outer London bus zone. For bus purposes, the single outer Zone was renamed Zone 3 while for Underground purposes they were numbered 3a, 3b and 3c the further one progressed away from the centre. So far as the Underground is concerned, the structure of the zonal system and stations situated in each zone are essentially the same today as they were constructed in 1983, though Zones 3a, 3b and 3c soon became Zones 3, 4 and 5. In January 1991 Zone 5 was split into two and the new zone, Zone 6, became the outermost. It was therefore apparent quite early in the development of UTS that it would need to be designed to accommodate a zonal fares structure and

that by the time it was implemented the whole scheme had to be refocussed around the new zonal system.

Travelcards

Zoning profoundly affected the idea of season tickets, as tickets between specific stations would no longer be issued. And so was born the Travelcard. These going to replace all season tickets and would (at least in theory) be issued for only one zone or between consecutive zones, with an all-zone Travelcard also available. Travelcards would also be available on London buses for travel in the same zones but a Travelcard covering any of the three Underground zones 3a, 3b or 3c would be available for the whole of Zone 3 on buses.

Examples of early roll-fed UTS tickets printed on various batches of yellow paper. The fare paid appeared in bottom right corner but on station of origin tickets the figure between the asterisks (the adult single equivalent fare) was shown prominently to aid manual inspection.

Above is selection of period tickets issued on pre-printed stock from the UTS ticket office machine. At top left is one of the few surviving season tickets used to handle short cross-boundary journeys. The other two green tickets are adult and child 7-day zonal tickets (longer periods were similar but different colour). Orange stock was used for tickets not requiring photocard (including car park tickets). The bottom right ticket was pre-printed and pre-encoded and was issued by agencies who stamped day on front. This was dated by ticket gates on first use (at Underground stations these tickets were printed on demand on yellow ticket stock)/

This wonderfully simple concept was harder to introduce in practice for several reasons. First, a number of stations were outside Greater London and these were outside the zonal system. At these stations, season tickets continued to be sold, either point-to-point for local journeys or from a particular station to a zone if the journey included Greater London. Secondly, there were some very short journeys that crossed a zone boundary where passengers would end up paying for a 2-zone Travelcard at very high cost. These journeys were identified and season tickets continued to be available on an exceptional basis for several years. Thirdly, a problem arose where passengers travelled across central London from (say) Zone 2 in West London to Zone 2 in East London. Passengers were required to pay for all zones along the journey and would require a Zone 1+2 Travelcard but obviously there would be a temptation to buy only a Zone 2 card (which was considerably cheaper as a premium was charged for Zone 1 travel); detecting such use would be difficult. In the end varying code letters were prominently overprinted in different sectors of London so that (say) a West London Zone 2 card, code W, would invite questions if presented at an East London station, code E

In 1984 a one-day Travelcard was introduced and was immediately popular. At the end of the year, an agreement was made with British Rail for the introduction of a series of zonal tickets on main line railways within London. This was launched in January 1985 as the Capitalcard and was available on Underground, bus and main line rail services using the existing zonal boundaries. It was priced slightly higher than the equivalent Travelcards reflecting wider availability. A one-day version appeared in June 1986. In January 1989, Travelcards and Capitalcards were merged, the more widely-known name 'Travelcard' was retained, but was available on Underground, bus and main line rail. This had become an immensely popular product and remains available today.

It will be helpful to remind readers that at this stage all tickets were of credit-card size card stock and bore a single magnetic stripe along the rear face containing all the necessary information within the magnetic code. Ordinary tickets were printed on yellow card, though this was later altered. These tickets were printed from ticket rolls at time of issue and for a time some of the white space on the back carried advertising. Travelcards and other multi-use tickets were printed on special stocks of individual card that were part-printed in advance and the final details and coding were added upon issue (this was a change from the Vauxhall experiment). Certain long term passes such as staff passes were printed on thin plastic material the printing included at time of manufacture and bulk encoded before issue.

The production Tenfare machines (redesignated Fewfare) were similar in operation to those at Vauxhall. The Allfare machines (by now referred to as Multi-fare machines), were similar in principle but the ticket type had to be selected before the destination while at Vauxhall it had been the other way around. A number of stations had latent provision for additional machines to be installed if required. In case of query, the source of each ticket was indicated by the 'ticket window number', from 01 upwards, or machine number, usually 10 upwards. Under UTS, everything had a number.

Stored Value

At about the time the whole of Zone 1 was gated serious consideration was given to how stored-value tickets might be introduced using the existing magnetic ticket equipment. This was by no means impossible and the equipment was designed with this possibility in mind, but it was very challenging and suggeted full gating would be needed. A specification was drawn up in April 1991 for a Zone 1 trial, but even this was going to be difficult and in the end it was decided to wait for the time being. We will see shortly how it was done.

More gates

At first only 63 stations were gated but there were a few troublesome stations just outside the gated area where ticketing compliance was troublesome. These stations were Stockwell and Brixton and the decision was made to install ticket gates using part of the spares float. Installation was straightforward as

station design made provision for gating and the floor ducting for cables and air supply was already installed. The new gates went live on 9th December 1991 and resulted in a sharp increase in revenue, estimated to exceed £325,000 annually. At Brixton ticket sales rose by 12.9 per cent and excess fare receipts nearly doubled. In turn, this suggested a 2-year payback on the £623,000 costs, representing good value for money. In addition it probably reduced the risk of conflict between staff and ticketless passengers at those two stations.

A strategy for monitoring ticketless travel had been devised whilst UTS was being introduced and it appeared that the introduction of ticket gates during 1989, when full gating at the 63 stations was implemented, had reduced to about a third of the previous level and stood at 1.9 per cent. The average disguises possibly uneven distribution of ticketless travel as it was much easier to make a wholly suburban journey without passing through a gate.

While the UTS ticketing system was proving very successful and the gates had proved very reliable, where provided, it was a moot point whether the Stockwell/Brixton experiment pointed the way towards gating only additional busy suburban stations or whether to gate the whole system, thereby closing all loopholes. As it was, the large rump of stations outside Zone 1, where manual ticket checking was still in force, represented a serious potential source of loss. There were also staffing matters to consider, and the fact that in making provision for gating at all stations when the station works were carried out, some of the gating costs had already been incurred for which no return was being achieved.

Authority to Travel and Penalty Fares

Another factor causing uncertainty was the matter of penalty fares. Noted earlier was LT's pessimism in the late 1970s about the likelihood of getting powers to introduce penalty fares (an attempt was made to obtain powers for penalty fares on buses in 1978 but Parliament rejected it). Anticipating that there was a possibility of penalty fares on the Underground being authorized in the mid 1980s (what happened is covered shortly) London Underground adopted the idea of introducing Authority to Travel (ATT) ticket machines. It was at that time impossible to guarantee that there would always be an open ticket office at all times at every station, and without that certainty the operation of a penalty fare system would be very difficult. In addition there was still political pressure to reduce revenue loss through fare evasion and false accounting. ATT machines would at least help mitigate the problem (so it was thought) of getting ticketless passengers to prove where they had actually begun their journeys so the correct fare could be taken, rather than accepting a fare from the next station which is where many such passengers claimed to have come from. Unlike the 1977-8 experiment these machines would issue an ATT free.

On the right may be seen one of the first batch of red Authority to Travel ticket machines. Relief station manager Maurice Friend presides, and is pointed at the push button that issues the 'ticket'. Also shown are examples of the ATT 'tickets'. These were at first on ordinary green card stock but it was soon changed to orange to make the tickets more readily identifiable to a ticket collector at destination. They were of similar size to ordinary tickets.

The ATT machines were the old-fashioned sloping front ticket machines adapted for their new purpose by having the coin acceptors removed and ticket issue initiated by operation of a push button. To make them distinctive they were painted bright red, and they appear to have been mainly the stock of very early machines put on one side in 1977, but further modified. A feature of these early types was a slightly longer ticket and the month indicated by three letters. The idea was that these machines would be switched on during traffic hours in the event the ticket office was closed for any reason. Posters would be displayed instructing passengers needing a ticket to take a free ATT ticket from the red machine and show it at the end of the journey where the correct fare would be taken. Ten stations introduced the machines from 4th December 1983, a further seven came into use towards the end of 1984 but it wasn't until 1985 when the majority of machines, some 76 of them, were introduced, with another five in 1986. After that the programme stopped. By this time, as we shall see, a new ticketing system was in the offing and since penalty fares had not been introduced there was little point in installing more ATT equipment.

It will be noted the introduction of ATT machines was painfully slow and in an attempt to achieve the benefits sooner, from 8th January 1984 staff at all stations without ATT machines were required the leave the minimum fare ticket machine switched on where a ticket office was closed (normally ticket machines would also be shut down). Posters strongly encouraged passengers to buy one of these minimum fare tickets and expect to pay the difference (if any) at destination. Of course not every station actually had any ticket machines and a passenger had only to say he had not the right change by way of excuse for not buying a ticket. The results were probably marginal but it demonstrated a more concerted attempt to collect the revenue due than perhaps had been evident previously.

Although the expected powers to charge penalty fares were granted in the 1984 London Regional Transport Act, there was a reluctance by the minister to make the necessary order and complications around what BR was doing about penalty fares, as there needed to be some coordination. It was also felt that LT needed to do more to ensure passengers could always buy a ticket before travel and that robust processes were in place before penalties could be applied, so at the very least the ATT machines had to be shown to be reliable, always switched on when required, and their use completely understood by passengers. None of these was easy. It took further legislation in 1992, and many assurances, before LT was allowed to go ahead and it was not until 3rd April 1994 that a penalty fares system was introduced. By then all the ticket issuing equipment had been replaced and in theory at least ticket machines were always available and information about any station unable to issue tickets was readily available. It was obvious that this would mitigate to an extent the impact of not gating outside Zone 1, but the financial consequences were unknown until it has been implemented and left to settle down.

Whilst the cost of gating every station might not have been justifiable in simple terms there were definite advantages to doing so. One was that accurate data would be obtained about how every journey was made, simplifying revenue allocation for multi-modal tickets and encouraging their expansion. Another was that with new technology in the offing there needed to be some way of interacting with passengers at both ends of the journey. The obvious way was by having a ticket gate at both ends. By increments, it became obvious that the longer term advantages of having full gating outweighed the short term costs. We shall deal shortly with the way bus and rail ticketing technology merged, and how the money was found, but for now it is sufficient to say that by the beginning of 1997 the policy was to gate every station.

New Gate Designs

With new gates in the offing, the question arose about whether the existing design was appropriate and whether a less expensive model could be achieved. Experimental tripod versions were produced and installed at Dagenham Heathway (another troublesome station) on 31st August 1993 but once more tripods were disliked and the locals (especially those uncustomed to having a ticket) quickly made it clear that tripods were not going to be satisfactory. A paddle design was now considered essential.

There were, with hindsight, some issues with the original UTS gates. An important consideration followed a safety review after the King's Cross fire when it was recommended future gates should permit 'push through' in a serious emergency, following the principle of the panic bar used on fire doors. This meant a complete rethink about the paddle configuration and it was now felt gates should have no more than a single pair of paddles closing at right angles to flow (rather than being angled) and opening either way depending on flow. The existing gates were also rather wide and it was hoped a new design would be narrower making it easier to install and configure gatelines of adequate capacity.

The Jubilee Line extension was also a significant driver of change as the architects disliked the existing gates and wanted something better. Importantly, the signalling system on the Jubilee Line extension, the construction of which was in hand, was intended to use the latest technology and not need a compressed air supply, which would be a huge problem as the existing design employed air-operation. There was a belief that with modern signalling being planned for other lines there would soon be increasing difficulty in obtaining a compressed air supply more generally and it was necessary to consider an all-electric design, which would be future-proof.

The new all-electric design (later referred to as the Mk 1, or E1, gate) had much thinner stanchions, allowing much denser gate installation. The engineers claimed the new gate stanchions were only 155mm compared with 390mm of the old gates (which seems to have allowed for the fact the earlier gate paddles, even when folded, partly obstructed the walkway.

The experimental UTS tripod-type gates at Dagenham Heathway

Since usually only a single medial stanchion was needed per gate pair, rather than two in the earlier design, it was roughly possible to get three E1 gates into the space occupied by two air-operated gates. Gates of the new design were first tried at Dagenham Heathway in August 1994, where they replaced the trial tripod gates and were immediately found far more popular, as well as technically satisfactory.

Meanwhile London Underground had identified a number of 'problem' stations where gating appeared to be justified on a stand-alone basis and 22 stations in the outer area received gates in 1995, followed by another three in 1996; in each case the E1 gates were installed and this might be regarded as an extended trial where they acquitted themselves well.

Finally, the decision was made that all stations would need to be gated. This partly resulted from the success of the stand-alone installations just described

A gateline incorporating the new Mk 1 style all-electric ticket gates. As before, some were one way and others reversible.

and was partly driven by the imminent arrival of new technology that would be very difficult to implement without every station being gated.

The first station of the main programme was West Ham, commissioned on 4th July 1998, though this was combined with Jubilee Line works. The main programme began at Swiss Cottage on 23rd December 1998 and finished at Camden Town on 16th December 2002. Bank, on the Waterloo & City Line was not part of the programme was received a set of gates on 18th August 2003. The bulk of the gate installation work was actually carried out as part of the Prestige project, the details of which are given shortly

The Carnet Excursion

In 1996 London Underground introduced 'carnet' tickets, which were packs of ten single-journey tickets sold at a discount. The tickets were normal day tickets, each available for one single journey within a year of issue and bore a 'use by' date which was the last day of the month a year ahead.

In actual use carnet tickets had first to be validated, thereby encoding them with the actual date of use. At gated stations validation would be done automatically by the entry gate. At ungated stations (and at some interchange stations where entry to the system was possible from National Rail or the DLR) it was necessary to install carnet validators. These were adapted from the 'approach' end of the new all-electric ticket gates which contained the ticket transport mechanism—the gate paddles were not necessary. If an unvalidated carnet ticket were presented to an exit gate, or a ticket with an earlier date, then the gate would not open. Unlike ordinary tickets the tickets in a carnet could be used by anyone and were found handy in offices (for example) where staff could make use of them as required or by different members of a family.

By 2005 new ticketing technology was in use, rendering the carnet idea largely redundant and the facility was withdrawn and the validators later removed.

A free-standing carnet validator based on the magnetic ticket reading part of the E1 all electric ticket gate (without the gate mechanism).

New Ticket Designs

During the early 1990s some dissatisfaction became evident with the design of the various tickets issued by the Underground, buses, DLR and British Rail. This included widely varying designs by the various operators for similar tickets and incoherently laid out dot-matrix printing used on many of the varieties of ticket. These were perceived to be difficult to read by human ticket inspectors, were confusing to passengers, were not laid out intuitively and failed to represent the high standard of presentation London Transport aspired to aim for. After a lengthy period of review by a joint working party representing all these organizations, a new series of designs was arrived at early in 1993 where the tickets would conform to a common theme and the important

Examples of later UTS magnetic ticket designs, replacing earlier unsatisfactory designs. At left are day tickets (one, the return, has the later quadrant triangles). The layout has been modified and the underlying card changed from yellow to pink.

information was presented more clearly. The new colours were coordinated with British Rail's own new ticket designs.

A little later these designs were modified to incorporate additional revenue protection measures. Where tickets were issued outside Zone 1 they now included a series of coloured triangles that were associated with only that zone. This was to invite scrutiny where presented in a zone in a different quadrant as it was important to check that Zone 1 had been paid for. The new designs required substantial layout changes which required reprogramming the equipment, but the new designs have endured. Single tickets issued from rolls were changed to pink card but layout did not change very much.

Above are further examples of the new style tickets. At top are other day designs and below are examples of pre-printed card stock. At bottom are two green 7-day blanks for different ticket types. Other periods used different colours, the annual (shown here) uses gold print; annuals were printed on a plasticised card and inevitably gate use caused wear and discolouration. Similar information (eg zones) appear in a similar position on all ticket types. Tickets issued by other operators were as similar as the technology allowed.

Chapter 17
The Smartcard Solution

Smartcard Development Work

During the mid-1990s, it was becoming apparent that the passenger-operated ticket machines appeared complex and new technology was becoming available that would do a better job and provide much more flexibility, particularly the touch screen. Quite apart from the desire to improve existing equipment transport operators around the world were looking at smartcards to provide flexible ticketing options and a better passenger experience. Hong Kong Mass Transit had already seized the opportunity to use smartcards with development starting in 1993; the product (called the 'Octopus' smartcard) was introduced in September 1997. These cards were not only available on the very busy mass transit system but could be used as an electronic purse for a wide range of other services such as vending machines, convenience stores, parking meters and so on. They proved popular immediately and after a short time were used by the vast majority of the population.

Leaflet available to those participating in the Touch and Pass experiment

London had already looked at smartcards but developing a comprehensive system was expensive, perhaps risky and the existing UTS technology was all new which meant there had to be a compelling reason to change it (although adding new capability was attractive).

London Underground engineers were introduced by Westinghouse Cubic to their Go-Card system at its HQ in San Diego in 1989 and in May that year the Underground's executive committee authorized a trial in London. After experiments later that year, London Underground carried out a three-month trial with their Go-Card system at three stations in 1990. The experiment had been intended to run from 15th January 1990 using the ticket gates at St James's Park and Victoria, which were to be equipped with blue-coloured 'pods' immediately above the ticket slot; Green Park station was supposed to have been added to the scheme on 15th February and the experiment had been due to finish on 13th April. However, it appears all this was delayed and that the experiment actually ran from 23rd April to 22nd July 1990 when the tags were collected. The experiment involved 458 volunteer passengers and staff using any of these three stations and who were issued with smartcard tags. When presented to the pod, the tag would cause the gate to open (the passengers and staff retained their correct tickets and passes as the experimental tags were not on their own valid for travel). The tags were credit card size (86 x 54 mm) and 5mm thick.

Shown here is a gate fitted with one of the experimental blue 'targets' or smartcard readers and a passengers presenting it with one of the blue experimental tags. The white strip along bottom of tag carries the holders name.

A closer view of the initial touch and pass target

Another design of touch and pass tag, this one only 4mm thick and possibly produced for second experiment. These were rather ungainly and had a bulge where the chip (or possibly a battery) was located.

The equipment was supplied by Westinghouse Cubic Ltd who had experience in Hong Kong, Singapore and the USA with similar equipment, and the purpose of this was to demonstrate the reliability of the equipment and passenger reaction (which was favourable). At St James's Park a video camera monitored the modified gate so that the way the tags were used could be studied. On completion of the 3-month experiment participants returned feedback questionnaires.

The results of this showed that the smartcards were enthusiastically received and technically fairly reliable. However there were two build standards to which the cards were made, both similar quality in factory conditions but producing substantially different results in the field trial. User feedback indicated some concern about volume and weight of tags. During the experiment 190,000 passes were made at the gates and there were 52 failures of which just two were of one of the build qualities and 49 were of the other. 49 of these suffered for some reason a data reset, two were incorrectly encoded and one had been damaged. Amongst the problems static was thought to be a factor and the threshold by which the settings were retained was another. It was hoped the use of tags would show that gate-flow was speeded up and although analysis hinted at this the evidence was inconclusive because such a small proportion of passengers were using tags compared with flow of ordinary tickets. Controlled tests suggested a 17 per cent improvement in gate throughput was possible, which itself was an attractive goal.

A further six-month trial was undertaken in 1991, at just two stations, where feedback from the first trial was incorporated in a revised design of tag which eliminated most of the problems. These trials together with market research showed that the implementation of a contactless Smart Card system was viable on the London Underground.

Smartcards trialled on buses

In addition to ongoing investment and modernization challenges on the Underground, the management of bus ticket issuing machines for over 6000 buses was complex and expensive and not well integrated with the Underground or other modes. The DLR and Croydon Tramlink also had quite independent ticketing equipment, again quite inflexible and not well integrated with the Underground.

London Buses had been interested automating the fare collection process ever since it began switching to one-man buses, mainly to help reduce excessive boarding times. This was done initially by splitting the front entrance and providing a right-hand boarding path that took passengers past a turnstile controlled by a self-service coin-operated ticket machine. Despite valiant efforts to try and get this arrangement to work there seemed little prospect of success; the all-mechanical equipment was unreliable and passengers much preferred dealing with the driver. Only on the flat fare red arrow services was there any conspicuous evidence of success (both channels had machines and the driver did not usually collect fares), but no tickets were issued and the

equipment was simpler. A brief description of early Bus AFC experiments is given in Appendix 3.

In the end the strategy altered to one where off-bus sales of attractively priced passes was pursued. These were widely available through newsagents and from Underground stations and were sold in sufficiently large numbers to make possible a useful reduction in average boarding times. A range of bus passes and bus pass add-ons to Underground tickets was available during the late 1970s and early 1980s. The arrival of the travelcard in the 1980s further improved off-bus ticket sales, coupled with adoption of flat fares on individual bus routes which further reduced boarding delays.

An early 'new technology' experiment took place in Thamesmead from 22nd March 1987 and was called 'Autocheck'. The equipment was installed on about 200 buses serving 22 routes and serviced from four garages. Two types of equipment were tested, both prototypes for the trial, from Wayfarer MDL and Thorn EMI.

Passengers holding bus passes, travelcards and concessionary passes were issued with special tickets to operate the equipment during the experiment. The buses were split entrance with the left-hand stream passing the driver if a fare had to be paid. However both streams passed Autocheck equipment where the special tickets were verified, being inserted in one slot and returned in another, the magnetic code being read and rewritten inside the machine. Before launch, drivers were trained about the use of the equipment during the preceding few weeks, and to engage with the public Autocheck buses were displayed in town centres and large numbers of leaflets were distributed. This was supported by an advertising campaign.

Staff examining Autocheck equipment just before trial started. This machine is behind driver but another was provided opposite.

The idea was not pursued and effort shifted towards a future using smartcards. There were several reasons why London Buses were interested in smartcards, including the possibility of stored value tickets and (perhaps more importantly) the collection of accurate data about how bus services were being used, which would be a useful planning tool. In addition the pain of bus privatization would be eased with a technical solution available to capture passenger data to enable accurate revenue distribution. If smartcards were widely available they might reduce (or eliminate) the use of cash, which was heavy, had to be accounted for, was a security risk and was generally an utter nuisance.

London Buses embarked on its own smartcard experiments through some live trials. One took place between September and December 1992 on bus route 212 in north-east London, which represented a proof-of-concept. Here, staff and over-60 concession pass holders were the first to use the new equipment and then 1000 volunteers were sought from those already holding bus passes. This experiment employed an off-the-shelf system called Buscom and had been used successfully in Oulu, Finland. A card reader was fixed in position near the driver and passengers presented their card to the reader as they passed. The cards were credit card sized but slightly thicker, at 1.6mm and contained an EEPROM chip with 256 bytes of memory, although a larger capacity memory was being developed. The reader had the capacity to record each validation and store up to 1200 transactions for subsequent download in the depot. Communication was inductive via a coil in the card. Smartcards based on this system raised the possibility

A 212 Smartcard ricket in use in the Chingford experiment.

A bus used during the Harrow smartcard experiment showing on left a smartcard being presented to the ticket reader, and the associated ticket machine which showed the driver what was being presented.

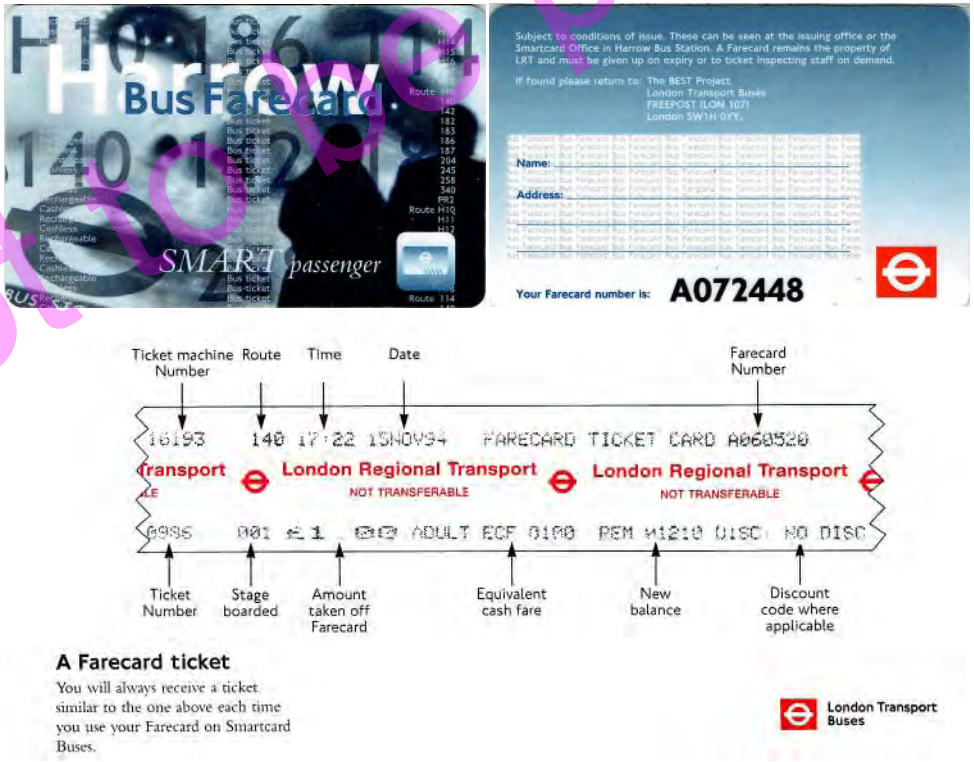
of stored value ticketing, felt likely to appeal to those not using buses every day, for whom the existing bus passes were not suitable. The focus was very much on targeting users currently paying cash, and attracting new users at a time when bus travel was diminishing, by making travel easier. In addition to validating what were in effect period tickets certain users (including students at, at least, one school) were given '212 Farecards' pre-loaded with 20 journeys, one of which was decremented each time it was used. Reports indicate the equipment proved reliable and found favour with passengers.

Having proved promising, the experiments culminating in a 2-year large scale experiment in Harrow where all buses were made smartcard-compatible (affecting 19 routes at first). The experiment was managed in two stages beginning in February 1994 for passes and long period tickets. For Stage 1, Harrow residents could arrange to have their ticket or pass details duplicated electronically onto a new smart photocard, which was checked by a reader attached to the bus ticket machine (and basically told the driver whether ticket was OK or not). There was also a staff photocard available to London Transport staff living in the area.

Part of the sealed Farecard pack available to passengers. The pack contained instructions, illustration of the ticket and a Farecard (the serial number arranged to be visible through a window on rear of pack). The pack included a small plastic wallet containing a leaflet listing all the PASS agents that could handle smartcards.

A year later, the experiment was extended by the introduction of a Farecard which was designed to test stored value ticketing. Passengers could obtain a Farecard and put money onto it for travel and the appropriate fare was deducted by the driver each time it was used on a bus (not all the Harrow buses then employed flat fares). The value could be topped up at a 'Pass' agent or actually on one of the Harrow buses. The initial Farecard carried cost £10 (the value of travel it carried) and it could be topped up in multiples of £5 to a maximum of £20. The mode of operation was to tell the driver where you wanted to go and that you wanted to pay by Farecard. The Farecard was then presented to the reader on the driver's ticket machine whereupon a special ticket would be issued in the usual way. The ticket contained both the journey details and the

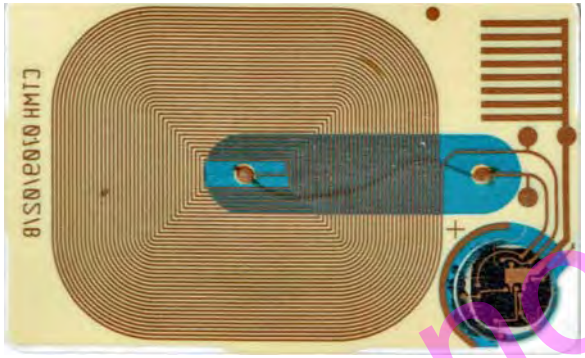
Examples (at reduced size) of smartcards used during the Harrow experiment. The set includes the general adult pass at top left and other variants including staff smartcard. These cards were 2.5mm thick and quite rigid.



Shown above are front and rear faces of a Harrow Farecard, issued as part of the joining pack. Underneath the Farecard is shown part of the explanatory leaflet showing an illustration of a ticket that would be issued for a journey paid for by Farecard. This also gives details of the Farecard used to pay for it and the balance carried.

starting and ending stored balance held on the card, the difference being equivalent to the fare just paid.

About 16,600 smart photocards were issued and 1137 £10 Farecards (half of which were subsequently topped up a total of 3092 times). The smartcards were of a type produced by GEC and the electronic reading equipment was by AES Prodata and was similar to that used in another experiment in Manchester. Market research showed the system was popular and it appeared to function reliably. All this was a good omen, but the question was how to take it forward.



This is the interior of a Harrow staff smartcard, which appears to have been built up in layers glued together using a glue that has failed to last 25 years (the Farecard seems to have been built the same way. The large coiled area is the aerial)

Chapter 18
The Prestige PFI Project and Oyster

The desire to replace some of the first-generation UTS equipment was referred to earlier, and, in particular, to replace the formidable push button ticket machines with touch screen technology, felt more user-friendly. There was some pressure to progress this new technology so it would be ready for installation on the Jubilee Line extension and a prototype touch screen ticket issuing machine was tested at Victoria towards the end of 1994, from which it was concluded the public found them an improvement.

LUL at first considered a project to upgrade its own equipment but then realized that with the ever-present shortage of capital, and government pressure to deploy further Private Finance Initiative (PFI) contracts, it might make sense to embark on a network-wide PFI arrangement with a supplier which would operate, develop and upgrade the ticketing across the whole of London Transport's operations (absorbing both the existing Underground and bus Smartcard know-how).

The outcome of this was that on 16th August 1998 LT entered into a 17-year contract with a consortium called Transys, to provide ticketing services on London Underground, DLR, Croydon Tramlink and London Bus services as part of the government's private finance initiative. The net present value of the payments was claimed in 1999 to be about £1.7 billion over the 17 years.

The experimental touch screen ticket machine at Victoria, probably in October 1994. This had the same functionality as an all-fare machine. A push-button type of few-fare machine may be seen to the left.

Transys at first utilized just 12 staff seconded from the various consortium members, noting that most of the actual work was to be undertaken by those members or their subcontractors so the permanent Transys staff was never very large. Cubic Transportation Systems was to install and maintain the assets whilst EDS was to manage and operate the system. Part of the incentive arrangement included a fee every time a smartcard was used, and it was very much in the interests of that company to promote the use of smartcards as much as possible.

The project (called Prestige) was to update equipment across all modes to reflect service experience and new technology that was available, gate 154 previously ungated stations and develop a smartcard ticketing system that

At top is a close up of the Mk 2, or E2, all-electric ticket gate which has been restyled to incorporate integral smartcard reader at mouth of ticket entry slot. The styling omits the TfL roundel.

Lower image is of a gateline using the E2 gates. At left hand end is a wide isle gate with two wide paddles. These are now standard and replace the old manual gates. Old gatelines also include these, usually with the E2 type stanchions.

would be easier to use, faster and more flexible than all the paper tickets in use and be available across all modes.

The highest priority under the PFI was the installation of ticket gates at outer London stations, work on this project starting on 22nd November 1998. This took over the work already started by London Underground, which had just begun fitting the new gates. The project ran very smoothly and the 51st station (Alperton) went live 19 weeks ahead of schedule on 5th April 1999 with work expected to be complete by year end. Enormous effort was required equipping other ticket outlets and ticket checking arrangements. For example 3950 buses had to be equipped with electronic ticket machines and smartcard readers and all 2263 shops that sold tickets as PASS agents required new equipment. Transys also took over 'ownership' of the existing ticket issuing assets with the responsibility for maintenance and renewal. It also took over 71 existing staff in October 1998 and a further 58 in February 1999. This also included the operation of all the accounting and management processes required to make the ticketing and accounting systems work.

The upper image is of one of the production models of the Jubilee Line extension touch screens for which production was in hand in Summer 1997. It appears to be at manufacturer's works.

Below is an image in late 1998 (or early 1999) of an all-fare touch screen machine on trial at an (as yet) unidentified station.

Between 2000 and 2002 work took place on upgrading the multifare passenger operated ticket machines with smaller equipment based on touch screens rather than a huge array of buttons. The equipment was a development of LT designs deployed, with success, on the Jubilee Line extension after trials at Victoria (referred to earlier) and then from June 1995 at Finchley Road where another 6-month touch-screen trial was undertaken incorporating the Victoria feedback. The screens had the added advantage of showing menus in several foreign languages and the new equipment could also accept credit and debit cards. It was hoped that the new machines would reduce queues at ticket offices and make the LU system easier to use, improving the user experience. The first two Prestige machines were introduced at Temple, in May 2000, followed by West Brompton. The upgraded machines retained the existing ticket printing and coding mechanism and it was just the button units and associated processor that needed changing. The touch screens were of the accoustic wave type where placing a finger on the glass locally absorbed ultrasonic waves passing through the glass screen and detectors identified which paths were stopped and therefore the location of the finger. This type of screen was thought particularly robust and tolerated a wide range of external conditions.

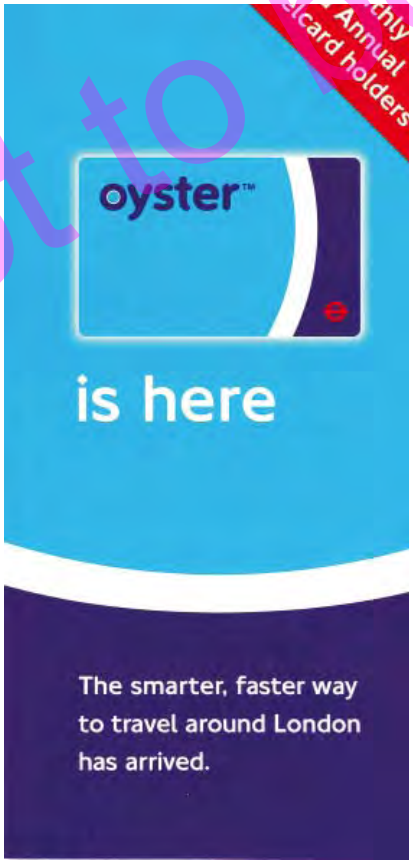
At the same time new equipment in the ticket office was expected to make the job of ticket issuing staff easier, and was designed to do away with the huge paper trail required by the traditional method of recording season ticket (Travelcard) information that dated back to the 1920s. This, too, was intended to speed up ticket transaction times. Enhanced equipment for accepting credit and debit cards was installed at the same time. As part of the upgrade all the station computers were replaced with more modern and versatile (and much smaller) equipment together with a new communications system. This allowed real time communications to take place and information to be stored centrally and accessed from stations as required.

New ticket office ticket issuing equipment introduced at Ruislip in July 2001

After three years of intensive development work, Transys came up with a fully worked-up scheme to introduce smartcards and during 2002 installed smartcard readers on the right-hand top housing of all the Underground's ticket gates. Also installed was the necessary ancillary equipment and software to issue and decode smartcards and operate the ticket gates (nearly all the later installations used the all-electric E1 gate, already used on the Jubilee Line extension, which included an integral reader at the front, above the paper ticket slot). After a great deal of brainpower had been expended, Transys opted for the non-transport related name 'Oyster' for the new cards, with a clear nod towards Hong Kong's Octopus card (the names Gem and Pulse were also considered). At this stage it was thought possible that Oyster might be used for services other than transport, though events did not in fact move that way.

After several upgrades this is a typical ticket issuing suite at an Underground station. New touch screens replace the old buttons and facilities are installed to recharge Oyster cards. There is an adjacent Oyster vending machine.

'Oyster' smartcards were initially provided to active staff who began using them in September 2002 as part of a lengthy extended test period. Retired staff also received Oyster passes in March 2003 and by the time of public launch there were already 80,000 'staff pass' cards on issue which demonstrated that the basic touch-and-pass concept worked without too many teething problems. Oyster was launched to the public on 30th June 2003, though initially only on a limited trial of 5000 passengers. The general launch did not take place until 5th September 2003, once the initial trial had shown itself to work. From then on, passengers could buy tickets as required using the internet or phone as well as at ticket offices, travel information centres and 2200 shops accredited as PASS agents. Once the commercial transaction had been completed the purchaser nominated a station and on next presenting their card at that station the appropriate ticket was loaded (this is because data between station and central computer was at that time exchanged only each night). The cards were very quick to interact with the gate equipment, transaction times were expected to be between 100 and 300 milliseconds. This speed was dependent on keeping the transaction simple with data stored on the card; at that time it was felt a



more elaborate arrangement would slow down transaction times, and hence impact on passenger flow.

At this stage the public cards were used purely for holding either monthly or annual period Travelcards then on offer; weekly Travelcards were made available on Oyster from 6th October by phone or internet, and from 11th November via LUL ticket offices. Freedom passes were added to the Oyster range in 2004, but had a different design of card. During 2004, Oyster cards became the only means of buying monthly and longer period Travelcards at an Underground station and from September 2005 the only means of buying weekly Travelcards. A useful attribute of holding travelcards and passes on Oyster cards is that lost and stolen cards can be identified and invalidated by the system.

In parallel with the installation of equipment on the Underground the whole of the London bus fleet was equipped with new electronic ticket machines that

After Oyster began to dominate ticket sales vending machines were installed to allow passengers to obtain cards and then charge them up on the equipment. These were later superseded by vending machines built into the wall of ticket issuing equipment.

included a customer-facing Oyster reader and as the new cards came into circulation they were usable across the London bus network. At this stage, buses still took cash and issued paper single-journey tickets for anyone without an Oyster card.

The smartcards included a built-in aerial and although passengers were encouraged to 'touch and pass' each Oyster reader the cards could be read from a distance of up to 10cm and did not need to be removed from any wallet they might be carried in. The first stage involved about 5000 annual and monthly Travelcard holders being issued with Oyster cards. At the end of October 2003 190,000 (public) Oyster cards had been issued, of which 160,000 had been sold at ticket offices and the balance by phone or internet.

As implemented, the system consists of over 4,000 ticket selling facilities, 16,000 ticket validators, a network of over 300 sub-computers tied into a Central Computer System and various other supporting elements

The next significant development was the launch of Oyster Pre-pay (later re-styled Pay-As-You-Go). This was (at last) the implementation of what had in the previous decade been called stored value ticketing. The facility was launched on 4th January 2004 and involved passengers buying a certain value of travel which was 'carried' on the Oystercard. Each time a journey was undertaken the value of that journey was deducted from the value carried until the stored value was exhausted. To help passengers, the touchpad mount had a small display unit in it that showed the amount of fare paid and the amount remaining.

The system depended on a passenger touching in at a gate at the start of a journey, allowing the Oyster card to record the station of entry. At the end of the journey it was equally vital to touch out so the value of the journey could

be calculated and deducted from the value stored and the new amount recorded. Although the system worked reasonably well, it was not entirely trouble free and some detailed adjustments were needed that will be covered later. Oyster Pre-pay was also introduced on buses during 2004. In fact the mechanics of pre-pay had been carefully thought through so as to encourage the passenger to touch out correctly whether the ticket gates were operating normally or had been left open for some reason. It worked because at the start of a journey the maximum standard fare was deducted and on touching out the correct fare was established and the balance refunded: it was very much in the passenger's interest to touch out.

The actual introduction of Pre-Pay was a huge challenge. Most (but unfortunately not all) staff had been trained but passengers found some aspects of the new facility baffling at first. Confusion was especially evident when a card that already had a Travelcard on it was also loaded with Pre-Pay (to facilitate travel outside the zones paid for). It was then discovered some passengers were making legitimate journeys that had not been anticipated, with unexpected ticket behaviour resulting. There were also some coding errors where some detail had been got wrong. However, the problems were identified very quickly and put right and it wasn't too long before passengers began to get used to what had in fact been a huge ticketing revolution.

Leaflets were produced to introduce and inform each successive Oyster development. Shown here are leaflets for price capping and for Pre-Pay

Coinciding with the launch of Oyster it was necessary to set up a customer service centre purely to deal with passenger queries, reports of lost tickets and refunds. At first, the slow start and limited range of fairly simple tickets meant the service centre wasn't very busy. Once Pre-Pay started, the number of calls vastly increased and by the very nature of Pre-Pay remains high, though not very different from what was expected. At stations, staff were issued with hand-held readers as it was not possible to see what information was held on an Oyster card just by looking at it. It was soon found that more machines were needed and 450 machines of an improved design were also distributed to stations before Pre-Pay was launched. These proved invaluable in resolving issues. Errors happened but the call centre could immediately identify the journey that had gone wrong and could refund the balance to the card next time it was presented. Passengers could also present their ticket to any ticket machine and see for themselves the journeys recently undertaken and what charge had been made.

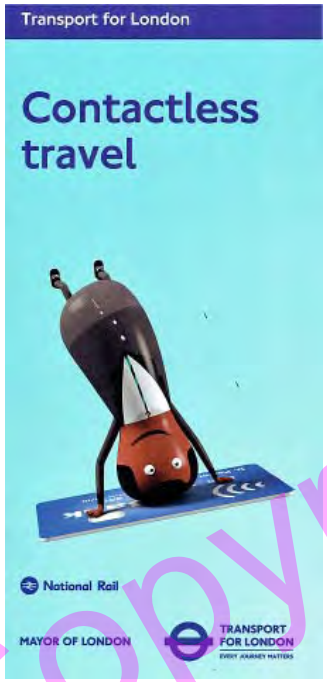
With Pre-Pay proving immensely successful, it rapidly reduced pressure on ticket machines as many passengers abandoned the use of paper tickets in favour of Oyster. The switch was encouraged by introducing and gradually increasing a price differential between Oyster Pre-Pay and cash fares taken mainly by machines issuing paper tickets. Daily price capping was introduced in February 2005 so that (for example) passengers making several journeys would pay no more than they would have done had they bought a 1-day Travelcard; this extra flexibility was very popular. From September 2005, passengers could arrange to have their Oyster card topped up from their bank balance automatically if the Pay-As-You-Go credit fell below a threshold, a system called Auto Top-Up.

By the end of 2007, over 10 million Oyster cards were in use and passengers could top up cards and renew travelcard facilities from the comfort of their own homes using the internet, the cards automatically being updated when next presented to a ticket gate.

No Ticket Needed

The next major development on buses took place in December 2012 when it became possible to pay without using tickets at all. Over the preceding decade, most credit and debit cards had been available with a 'touch' facility which allowed the card to communicate with readers to allow cashless payments to be made without inserting the card into a reader. This system was compatible with the Oyster readers and since buses used flat fares it was easy to arrange for that fare to be deducted if a suitable credit or debit card was presented. Within two years 69,000 journeys a day were paid for this way.

Extending this to the Underground was rather more complicated, but it was achieved from Tuesday 16th September 2014 when it became possible for a passenger to touch in and touch out on the Underground using a credit or debit card, it being, of course crucial to use the same card in each case. The thinking relating to its use was the same as for an Oyster journey with an amount notionally being deducted on entry and balance returned on exit. The mechanics are quite interesting. Upon a card being presented on entry a virtual ticket is created on a central computer and this is identified by the card number. On exit, the station of exit is recorded with the fare due. If the passenger travels again with the same card the process is repeated and the information is recorded on the same virtual ticket. Each night the journeys are totalled (including any bus journeys), any appropriate price cap is applied and at that point the card-holders account is charged. Again, incomplete journeys attract a high fare but this can be resolved by the call centre in the usual way. The virtual ticket arrangement means the system knows a passenger is in transit and that the various laws applying to the need for a passenger to have a valid ticket are complied with. TfL refers to this facility as 'Contactless'.



At top, a contactless transaction taking place on a bus-mounted Oyster reader and (below) a more recent innovation comprising a near-field smartphone being used at a ticket gate at an Underground station

Within a year 1.2 million journeys a day were paid for using 'Contactless' and TfL decided to extend the facility to Apple iphones using the near-field facility with which they were fitted, and Apple Pay as the payment medium. The process was similar to debit cards but recorded the phone number instead of credit card number. The facility was extended to Android phones from 16th May 2016 using Android Pay.

The End of the Ticket Office

There is no doubt that Oyster has been tremendously successful and (provided it is accepted that passengers must pay somehow) now offers a flexible and fair means of payment. Once pay-as-you-go had been introduced, with topping up automatically or from one's own home, or phone, the use of ticket offices declined rapidly and was really only helpful where prospective passengers were unfamiliar with London or there was a problem using the machines. Perhaps spurred on by cash shortage LUL examined its system of ticket selling in some detail and concluded that provided there was always a member of staff to

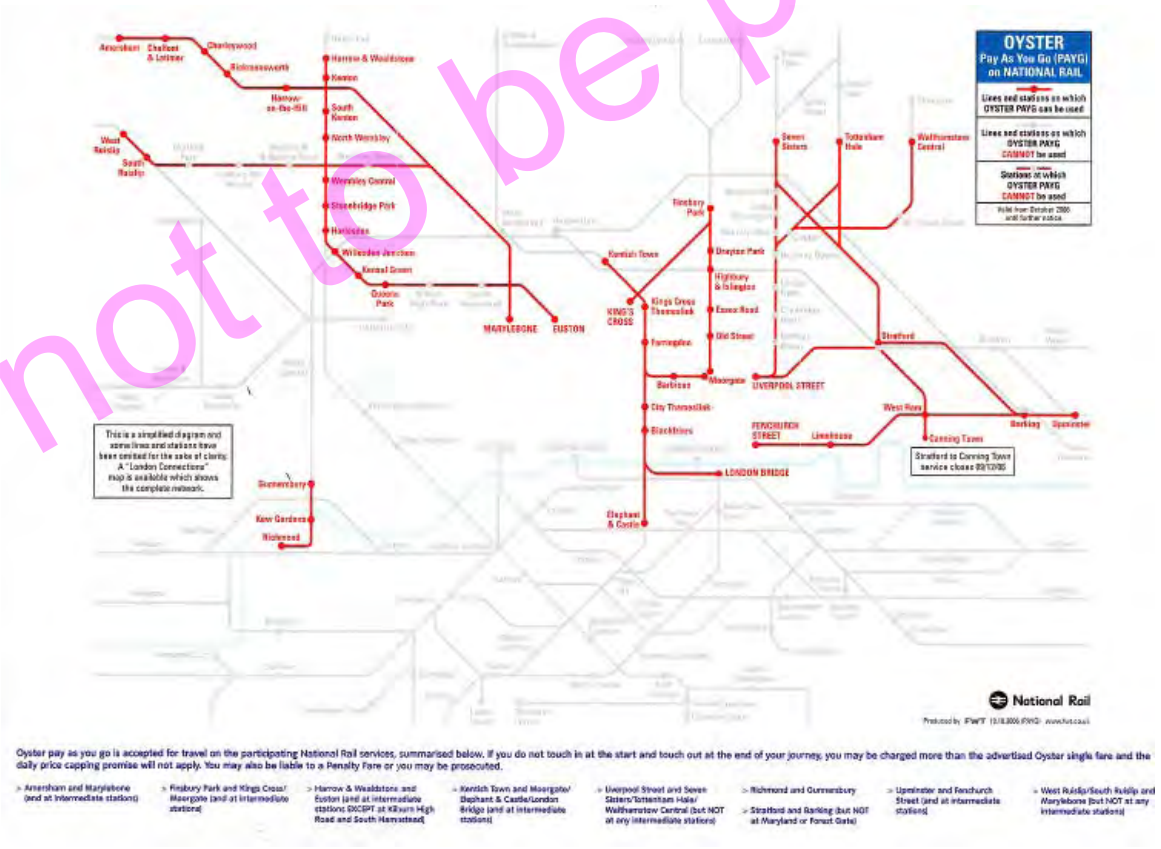
assist in the ticket hall the booking office itself was redundant.

This revelation, which was found controversial by many, resulted in some of the automatic ticket issuing being modernized, upgraded or supplemented, staff being retrained and issued with tablet computers that could answer all kinds of complex queries, and a massive effort being made to make passengers aware that all tickets they might want could be purchased with ease from a machine. At small stations the gateline staff were basically redeployed to assist at the ticket machines and at busy stations extra staff were employed to do this. With all this in hand the brave decision was made to shut down the ticket offices, and this was achieved over about 18 months after the first closures in February 2015.

The ticketing system is in reality in a process of continual change as technical and commercial developments and this seems likely to continue. For example the station computers that are at the heart of station operations were upgraded in 2002-3 to cope with smartcard ticketing, and the existing first-generation equipment was in any case obsolete. By 2016 these computers were in turn replaced by a Mk 3 version which was more powerful and much smaller. After a successful experiment at Tooting Broadway from November 2016 these were installed throughout the network between September 2017 and March 2018. Many station components are changed or updated on a routine basis.

National Rail

National Rail stations at the start of the twenty-first century were all equipped with computerized technology that printed tickets on blank cards at time of sale (the system was called Aptis). The cards were compatible with LUL's UTS ticket gates and were coded to operate them on valid journeys. The Aptis machines sold the usual range of tickets for through journeys to the Underground, including Travelcards. A few stations had ticket gates, but they were then uncommon on National Rail stations and only in the last decade did they began to spring up at the busier stations in larger numbers. They presented no problem for correctly coded LUL magnetic tickets. When Oyster cards were introduced, the seeds were sown for a mounting problem as National Rail stations were not at first equipped. National Rail stations continued (and still continue) to sell travelcards on card stock with magnetic stripes and LUL continued to do so for a few years; however there was obviously now a requirement at National Rail stations to be able to deal with passengers



This map appeared in a 2006 leaflet in order to try and address confusion over where PAYG ticketing worked on National Rail. It represents a grim offer.

turning up with a Travelcard on Oyster stock, which could not be checked by simply looking at it.

Hasty arrangements were made at those stations directly served by Underground trains by equipping them with ticket validators (and occasionally gates) and this spread to other stations where the equipment was justified. Where manual ticket checking was the norm, staff received hand held verifiers so they could check a ticket was valid.

The introduction of pay-as-you go on National Rail was a long and painful process, the default position being that this system was simply not accepted. Exceptions were made for stations served by Underground trains and where (because of this) pay-as-you-go validation facilities were already provided. This was really only done (and then grudgingly) because it could not realistically be prevented, for example Ealing Broadway to Greenford, but not intermediately. Oyster was introduced fully on London Overground services when TfL assumed control in 2007, and several operators accepted travel on parallel routes where it couldn't really be avoided, somewhat enlarging the facility on National Rail but creating mounting confusion at the same time. A few additional routes were added after TfL agreed to fund the equipment. The train operators argued there was nothing in their franchising agreements requiring them to accept pay-as-you-go and they couldn't see why they should accept its associated costs and bother and consequential commercial risk.

Where there were no gates it was necessary to install these validators at all National Rail stations where PAYG was to operate.

The public, however, loved Oyster and wanted to know why the train operating companies were so inactive. Very slowly, progress was made, fuelled partly by TfL being pro-active and partly by the bad publicity attaching to the train operators. The level of confusion was considerable and train operators came in for much criticism for their attitude to this and the lack of proper information about what was valid where. A precursor to integrating main line rail ticketing with the TfL system was the conversion of main line fares within London to a zonal basis, achieved (after some pressure) in January 2007.

Finally, from 2nd January 2010 Oyster pay-as-you-go was finally accepted anywhere in Greater London, the necessary ticket validators (and in some cases gates) having been installed at all National Rail stations in Greater London.

I give below the attempts made to achieve pay-as-you-go on National Rail quicker, from evidence given by TfL to the House of Commons Select Committee on Transport.

1. Before Oyster was rolled out at the start, Transys made an offer to all London train operating companies to install, for free, Oyster retailing capability at 250 or so London stations, but this was refused.
2. In 2004, TfL offered to finance £25 million worth of TOC investment in smartcard infrastructure required to extend Oyster Pre Pay to all rail stations throughout fare zones 1-6. This offer was refused, the TOCs claiming the actual cost was nearer £65 million. TfL felt this included matters nothing to do with pre-pay and resulted in short term dead-lock.
3. In 2005, TfL invested £500,000 to survey National Rail stations in an-ticipation of the extension of Oyster Pre Pay to all stations in zones 1-6. Many TOCs refused to review station drawings related to installation of equipment for extending Oyster to stations within zones 1-6. One TOC even demanded to be paid for the time of the personnel required to perform the review.

4. TOCs have raised concerns over the potential for fraud and revenue control risks with the use of Oyster on National Rail. TfL believe that this possibility has been overstated by TOCs. Evidence from the DLR and other works show that these risks can be managed and do not prevent progress. There were also concerns that the DfT was pushing TOCs into working towards national smartcard ticketing that might be incompatible with Oyster, but TfL insisted that Oyster would in no way interfere with any national scheme.

It is worth adding that *post-hoc* studies have suggested that introduction of pay-as-you-go by the TOCs has increased their revenues by 6 per cent, so popular and convenient it has proved to be.

Chapter 19
The Prestige PFI. What next?

The Cubic Factor

The firm, Cubic, has featured significantly in the recent development of automated ticketing in London. Originally just an American firm, it was created in 1951 by Walter J. Zable, a professional footballer and engineer who started off building digital voltmeters. The company developed rapidly, focusing at first on aerospace and defence but diversifying into the elevator business by buying US Elevator Corporation in 1969.

At that time several companies were courting mass transit rail operators hoping to introduce automatic fare collection systems, then at the cutting edge of technology. These included Litton Industries, Control Data Systems, General Electric and IBM. Litton came to own Advance Data Systems around 1964; this is the company London Transport employed to assist it in developing AFC, described in an earlier chapter. However in the late 1960s the various companies mentioned were becoming disenchanted with the slow take up of AFC and Cubic saw a market opportunity and decided to enter the AFC business. This was achieved by the takeover of Los Angeles based Western Data Products inc. This company was in the fare collection business but was not flourishing. It did, though, comprise a number of former Litton engineers and this was the foundation of Cubic's transportation division.

At about the same time, IBM was seeking to disengage from the transportation business and Zable was able to acquire, very cheaply, IBM's fare collection technology and drawings which gave the new arm a good start. Very quickly a number of large contracts for fare collection equipment were obtained, including San Fransisco (BART), Washington and Atlanta. In order to obtain European business Cubic teamed up with an established British company, Westinghouse, to create Westinghouse Cubic (WCL), a 50-50 joint venture company created to exploit fare collection opportunities based on Cubic know-how. The company was formed in August 1978 and was based near Redhill.

WCL quickly did business with London Transport, supplying a small number of automatic gates. These were presumably the slimline gates installed at the reconstructed station at Charing Cross for the Jubilee Line when it opened in 1979. The UK operation appeared sound but in America huge problems were emerging with equipment unreliability and Cubic's reputation was being roundly trashed. Fortunately, Zable was able to identify the weaknesses and bring the company round.

In April 1997 WCL took over Thorn Transit Systems International Ltd, a British company involved in automatic revenue collection systems and which during the 1970s and early 1980s provided ticket machines for the Underground following the demise of Brecknell, Dolman and Rogers, which had provided most of them previously. At the same time, Cubic followed up on a strategic decision to buy out the Westinghouse share of WCL and on 1st April WCL was renamed Cubic Transportation Ltd. By this time Cubic was the biggest name in fare collection technology.

Prior to this reorganization WCL became heavily involved with the experimental UTS installation at Vauxhall and with the introduction of UTS phase 1, the complete gating of Zone 1 stations with new pneumatic gates and removal of the old ones, the introduction of new ticket machines and ticket office equipment at all stations and provision of new 9.6 kbps communications system. Even by Cubic's standards this was a big project.

Background to the PFI

In 1992 the government launched its PFI initiative with the stated objective of utilizing perceived private sector know-how and efficiency and, probably more importantly, the unstated objective of keeping borrowing for public sector projects off the government books.

Meanwhile, as we have already noted, London Underground was hoping to install ticket gates throughout the system and install improved ticket sales equipment. Since 1984 the government had been in direct charge of LU and when discussions began about the substantial capital funding for the necessary upgrade work the government began guiding LU along the ideological road to private finance and it quickly became obvious that it was not going to be possible to obtain funding by the usual method. Various treasury-friendly sleights of hands were available to make sure PFI would usually be justified. One of these was an acceptable factor representing improved efficiency the private sector would bring. For example the incentive system would force the contractor to focus on the whole life cost of the equipment provided rather than (so it was thought) providing equipment which was inexpensive to start with and either difficult to maintain after the provider had walked away or where money would be made later from spares, maintenance contracts or replacement equipment.

Another claimed benefit was the concept of risk-transfer. The latter involved asset transfer to the PFI partner, who would own all the equipment and systems and be responsible for availablity and reliability of the service it then provided. LU would buy in the ticket and fare collection service on a daily basis and only pay, or pay the full amount, if it was delivered to the required standard. The service charge LU would pay included gradual repayment of the capital which the PFI partner needed to borrow. Risks included obvious project management delays and costs overruns a well as those of the equipment not working, or not being available at all, or not meeting the contractual regime in any way. These were to be entirely borne by the PFI partner and this risk transfer had a material value that greatly aided the business case. The idea of risk transfer for Britain-critical services has been much diminished in recent years since the reality is that if the PFI business partner collapsed it is inconceivable the service would be allowed to stop, and the government would be forced to step in, whatever the cost. This became all too clear when the Underground's later PPP contractors failed, but in 1994 LU had to follow the ideological mantra of the day and a ticketing PFI it had to be.

Important in the run up to this was the development work for the bus smartcard system, and within London Transport it proved possible to combine resources and go for a pan London Transport PFI. At that time the DLR was not part of LT and therefore not involved in this work.

A procurement notice was issued during 1996 for a proposed PFI along the lines just mentioned. The essence of it was that all the existing assets would transfer to the PFI contractor which would initially maintain them and in due course replace them all with new or modernized equipment that would meet the improved fare collection service TfL required. At the end of the contract the mostly new equipment would transfer to LT, but the intellectual property would belong to the PFI contractor who would grant LT a licence to use it thereafter (this later became an issue).

As part of the risk transfer process, LT had to specify precisely what ticketing services it wanted to buy from the PFI partner and leave it entirely to the contractor to determine what equipment was necessary in order to provide those services. Since LT knew it wanted to introduce smartcard technology this was a problem because the PFI rules meant they could not specify a specific ticket medium. It was possible to indicate that a 'new ticket medium' was required and how it should behave and these are the words that had to be used. Writing a service specification this way is very challenging since the only thing that is known is the existing service and reasonable enhancements that can be foreseen What is unlikely to be known is how technology would develop during the term of what could be quite a long contract and, therefore, how to try and encourage the contractor to adopt that technology at some appropriate moment since telling the contractor what to do was forbidden. Equally problematic was how to deal with LT changing its mind about some aspect of the service that was required, which was also unforeseeable. A schedule of rates for definite time spend doing some definite thing was incorporated but was unable to deal with consequential changes in financial dynamics, and this became another source of argument later.

Another problem the government financial gurus had not apparently considered was that in the case of ticketing automation there was not a very

vibrant market; in other words there were few large contractors in this very specialized field. Four consortia were shortlisted but three eventually withdrew from the competition leaving only the TranSys consortium, the name being a catchy shortening of Transaction Systems Ltd. This comprised Westinghouse Cubic, Electronic Data Systems (EDS), ICL Enterprises and WS Atkins. The first two withdrawn bids were led by Olivetti and IBM and then, at the last moment, the third bid, led by British Telecom, was dropped.

This was unfortunate from the government's perspective but in terms of value for money there was still the public sector comparator (PSC) test to ensure that the surviving bid was acceptable. In order to justify the PFI route an imaginary procurement was costed, based on traditional procurement methods and government funding. Since government funding would always be cheaper than private sector funding a traditional procurement option began with an advantage. Ultimately it came down to the value of efficiency and risk transfer benefits outweighing the slightly higher cost of money. For this to happen (and I think it always happened at LU) it came down to the assumptions made about the value ascribed to risk and efficiency, for which guidance had been provided. I do not of course go so far as to suggest the weightings these factors were ascribed were designed to ensure government policy PFI would always win, though others might.

The obvious problem with a PSC is that unlike a real PFI bid, the PSC is put together by the end user who specifies exactly what equipment is wanted and makes all kinds of assumptions about maintenance, technology change, future ticketing requirements and so on, all of which means making another load of assumptions that might be reasonable or not. The comparison process therefore compares two very large numbers both much influenced by rather a lot of assumptions. Where this is calibrated through receipt of multiple bids from credible bidders the factors weighing on the PSC can be better considered, but where there is only one bid it is more of a challenge.

What LT was asking for was a vast contract that was difficult for any one firm to finance, even a large firm like Cubic. Some £190 million of debt would have to be raised for which guarantees would have to be given, and few firms around the world would have found it easy to do this, and certainly not Cubic. It was fortunate that Cubic had already been talking to ICL about provision of a central system and retail terminals in order to meet requirements of its existing contract, and ICL was persuaded to join Cubic in the PFI bid. EDS was another large company with skills in building and operating technology contracts and Atkins was skilled in on-site works. Between them a credible source of finance was possible.

A 17-year contract was signed on 16th August 1998 and Transys took over. Both Cubic and EDS had an equal shareholding of 37½ per cent whilst the remaining 25 per cent was divided between WS Atkins (5 per cent) and ICL Enterprises (20 per cent). ICL was later rebranded as Fujitsu Services, it had been owned by Fujitsu since 1990. A decade later EDS became part of Hewlett Packard. It was envisaged that virtually all the work would be undertaken by the two largest shareholders and that Transys would pass service fees through to the contractors doing the work and not itself be a large entity.

The PFI Awarded

Five early project milestones were critical to its success; the first three were completion of installation of ticket gating, upgrade of the various Underground ticket machines, and upgrade of all the bus ticketing equipment. During this time London Transport was being subjected to the PPP initiative as well as transfer to the London Mayor and Assembly in the form of Transport for London. This was a very difficult time all round and the Prestige contract was not made easier by having to work through three shadow infrastructure companies about to be sold. Nor was it convenient that the bus business was transferred to TfL on 1st January 2000 whilst the Underground side came over in 2003.

These administrative challenges were not, however, the cause of some difficulties arising with Prestige quite quickly. The problems were arising with the ICL elements that included the provision of new point of sale terminals and new station accounting systems, without which the milestone for the

launch of smartcards was at risk. This would have been very expensive for Cubic, to which ICL was contracted.

However TfL had now inherited Docklands Light Railway and Croydon Tramlink (which opened in 2000) and it became obvious fairly quickly that these two concerns needed to be included in the Prestige system if ticketing was to be properly integrated. This meant a contract variation was necessary. Secondly there was mounting nervousness about the original idea to introduce smartcards in a single 'big bang', as this was very risky (though Transys had technically taken on this risk the fact was it would be TfL that would carry all the flack and this was an early lesson in the realities of risk transfer). During the subsequent negotiations Transys took on the upgrading of DLR and Tramlink ticketing, worth another £8 million investment) and a phased introduction of smartcards was agreed, phase 1 being June 2002, the date the whole thing should have happened. The final phase was not actually completed until November 2006. In order to recover some of the slippage ICL's part of the work was taken over by Cubic, though ICL (soon Fujitsu) remained a shareholder.

PFI Problems

Several problems presented themselves. A major one was responsibility for marketing the new ticketing system and the Oyster brand. It had been imagined in 1996 that the Oyster card might be used as an electronic purse and that an imaginative contractor would want to promote the use of this handy new London smartcard for all kinds of purposes being bus and rail travel. Transys would make money and LT/TfL would take a cut. This simply did not happen. Within Transys marketing responsibility lay with EDS which appeared increasingly disinclined to take on more than was actually necessary under the contract and TfL thought this was not even enough to promote its use to TfL users. After some wrangling responsibility for marketing was taken on by TfL instead, but use of the card outside the London transport network was effectively abandoned.

Very slowly it became apparent that initial Transys enthusiasm was waning. In 2004 when pay as you go was about to be launched TfL thought Transys (in practice EDS) should set up a proper support system for customers when the inevitable problems arose. EDS took a more negative view and this resulted in TfL setting up a proper system which experience later showed had been necessary.

There were a number of further issues brewing up but TfL began to get very interested in the possibilities of contactless payments. The problem here was that it meant significant savings that would accrue to TfL with no commensurate benefit to Transys and a great deal of extra work. These misaligned incentives, unforeseen in 1996, were now a problem. Transys could be induced to do the work but not to do so economically. In any event it appeared that some of the things they were already doing did not offer good value for money.

There was also the matter of performance. Transys was certainly always meeting the performance standards in the contract (written at a time when the performance of the technology was unknowable) but TfL wanted better performance and believed it was achievable. Transys did not see why they should go to the expense of improving performance when it was not necessary (in its view). Issues also arose about the desire to roll in the main line train operators, about which Transys was not very enthusiastic (nor were the train operators).

These are examples of things arising which were not adequately covered in the PFI contract when it was written. The deficiencies became apparent only some years later. One can be critical that with a long contract and many things quite unknowable some mechanism for change should have been allowed for. Technology was bound to move on. Some things arguably were foreseeable. A difference of opinion about whether a price was the price or the maximum price ought not to have been ambiguous, for example.

The PFI contract contained a break clause that could be exercised in 2010 with two years notice and this was a worry to Cubic, which had more or less achieved its own obligations. It will be apparent that a long contract with an unconditional break clause in it is in reality a short contract (to the break point) with an extension merely possible. It would be most unwise to rely on the

second portion. Cubic's problem is that Prestige represented 40 per cent of its worldwide business.

Termination

Recognizing that the PFI was beginning to fail and that there was a break opportunity looming, TfL attempted to negotiate with the two major shareholders. Cubic was eventually receptive because it had very little option but EDS was not very cooperative and TfL soon concluded that further attempts to negotiate would be unproductive. TfL wanted a number of things around the intellectual property, including its own access to it and ownership of any new intellectual property. There was also an issue around how its ownership and management were arranged at the end of the contract which TfL wanted clarity on, since the contract as it was left ownership with the contractor which might be problematic if TfL wanted to appoint another contractor. TfL wanted a better performance regime, open book accounting and lower costs. Many of these factors were not in the spirit of the original PFI and were not going to be conceded willingly. However, TfL held the ace card which was the termination option. During early 2008 it was obvious TfL meant business, as it was building up its own in-house team to replace all the lost experience consequent on the original team being transferred to Transys. The appointment of two managers, one of whom left Cubic and the other EDS, was evidence enough that LU was not going to let the challenge of getting a better deal go away.

The only mechanism for getting a better deal was direct negotiation with Cubic and getting out of the PFI. Notice was given in August 2008, to take effect two years thence. In its place would be a direct contract with Cubic which would subcontract some of the activities to EDS, by the time of termination knows as Hewlett Packard (HP). LT claimed what was called the Future Ticket Arrangements contract would produce savings of £11m a year.

What had to be done was quite complicated. For a start the intellectual property in the Oyster brand was owned by Transys and had to be purchased from them, which cost TfL £1 million. Then the outstanding debt of £63 million had to be paid off by TfL in accordance with the old contract terms; this was repaid by TfL on 26th February 2010. From that same date the various assets in the form of ticket gates, ticket machines and all the other paraphernalia that were owned by Transys were formally transferred to TfL. and sat on its balance sheet.

Cubic decided it was unwise to rely on some of the existing operational systems that functioned from HP's own data centres and decided to operate them from its own; this included all the communications links to the stations and bus garages. The work was put in hand in February 2010 and completed over the weekend 24/25 July, in plenty of time for transfer of responsibilities on 16th August.

Transys (Transaction Systems Ltd) continued as a wholly owned subsidiary of Cubic and only in July 2016 was renamed Cubic Surface Transportation Systems Ltd, still based in Redhill..

Life After Prestige

Lest it be thought the Prestige project was in any way a disaster, this would be a most inaccurate characterization. At the start it performed as well as could be expected and the various early misfortunes were largely fixed. Whether LT/TfL, distracted by the political and organizational changes could have done any better (even if they had the money) is uncertain, but I think unlikely. Whether it could have been done cheaper we cannot know since it depends on whether the project under LT control would have been delivered to maximum efficiency and completely without delay, whilst Transys was paid to carry that risk, rather like an insurance policy. It might have been cheaper, but probably not by much. The issues really arose when the contract moved beyond the period of known outcomes into unforeseen territory which exposed the misaligned objectives.

So what did Transys achieve? It was successful in raising investment money and borrowed £190 million from several important lenders. The whole of the outer London network was gated, the whole of the Mk I fleet of passenger operated push-button ticket machines were replaced with new equipment,

smartcard technology and pay-as-you-go technology was introduced with conspicuous success and the Oyster brand was born. There were small upsets (brief system outages) but these were exceptional. Basically the technology and the underlying systems worked very well and it is to the credit of the main consortium shareholders.

I have already touched on the matter of risk transfer and how hard it is to transfer very much real risk to the private sector, nevertheless there was some and it did work. A system outage caused by a software problem caused the Oyster system to pack up on 12th and 15th July 2008 losing TfL much revenue. Under the contract this lost revenue (or much of it) was recoverable from Transys and when the Mayor was questioned about this shortly afterwards £1 million had already been recovered.

What was disappointing was that Transys had the right to identify and develop other uses for the Oyster card beyond TfL ticketing and were incentivised to exploit those rights, presumably an idea sparked off by what the Octopus card was being used for in Hong Kong. These rights were not used and it would be interesting to know if Transys ever had a plan for using them. Perhaps the appointment only of technology companies was a poor foundation and lacked entrepreneurial flair. It is instructive that as soon as TfL acquired the intellectual property it claimed to be marketing the brand for other purposes and were looking for an early return of £1 million a year.

In 2005-6 TfL had been claiming that the cost of revenue collection was 14.3 per cent of the revenue thereby collected. After getting rid of the PFI deal it had settled down to 8.8 per cent in 2012, much lower than in comparable European systems. Of course the lower percentage was from a higher income base and it is doubtful the relationship between revenue and cost of collection is linear. Even so (and after allowing for inflation) this represents perhaps a 20 per cent real cash saving, which is still well worth having.

What next

After Prestige, the most noteworthy improvement was the development and introduction of the contactless system which gets rid of the traditional idea of a ticket altogether.

TfL is particularly pleased with this contactless system but has problems with still-popular Oyster. The main challenge is that with Oyster (but not contactless) all the information about usage and validity has been held on the card itself. This reduces flexibility and ability to correct errors as the back office systems can only intervene when a ticket is presented to a gate. A new generation of Oyster cards has been in circulation for some years and these could transfer journey information to the central computer in the same way the contactless system does, but at the moment the old Oyster platform remains in place.

These second generation Oyster cards are compatible with a future system that stores information centrally rather than only on the card, improving possible functionality. A replacement platform is now being sought where the necessary information is stored centrally and altered on the fly as tickets pass through the system and this will probably require the retirement of surviving first generation Oyster cards. Whether the name Oyster survives this, we will have to see, but smartcards in one form or another are here to stay; even if contactless becomes the norm, large numbers of smartcards will be necessary for staff and contractor use and for people who do not have credit cards. Perhaps the real question is around paper tickets that require the use of mechanical ticket transporters with their attendant cost and maintenance needs. The obvious constraint is the need to accept through paper tickets from main line rail, where ticketing policy is a complete mess.

In July 2014 TfL signed a further 10-year contract valued at £660 million with Cubic Transportation. Called 'Electra' this covers maintenance and provision of all the fare collection equipment on 8,500 buses, 1,900 ticket gates on Underground and Overground stations, and 1,800 standalone ticket validators. In addition it covers National Rail's 1,600 TfL-compatible ticket machines (at

250 London stations) and 4,000 retail devices located at the various high street shops and agencies that sell Oyster ticket products in London.

Appendix 1

The ADS Recommendations 1965

The report from Advanced Data Systems is dated 15 April 1963 and pre-dates many of the trials and planning undertaken by LT. Described as a feasibility study, it examined the nature of the existing ticketing system, how it might be automated, and in what direction planning might proceed. It was not 'manage-ment heavy', being researched and written in about a month by two engineers from Los Angeles who came to London, though it was informed by development work already undertaken for transport undertakings.

Important to the problem to be tackled was the finding that there were over 30 types of ordinary tickets, 17 types of season, 4 rover tickets, paper tickets (where fares but not a particular tickets were available) and parking tickets. Allowing for some sub varieties this produced a range of well over 100 ticket types. However, ordinary single and returns (ie just two types) accounted for about three-quarters of all revenue, and seasons about one fifth. Everything else accounted for the remaining five per cent, and it seemed that there was considerable scope for simplification.

ADS was keen to emphasize how an AFC system could reduce back office work. Back-office work then comprised a huge amount of effort both within the ticket office and at headquarters, with duplication and delay. The amount of paperwork was vast and the problem of extracting useful statistical data was exceedingly slow. Over a million tickets a day were collected and sent to a central office where a variety of checks and counts could be undertaken on a programme (or random) basis and some of the data analysis was exceedingly time-consuming (for example the 3-year route test of a 3-day sample took 16 man-years of clerical effort each time). ADS thought that barrier equipment could do much of this automatically. Significant staff savings appeared possible, especially if booking-clerk (ticket selling) positions could be reduced as a result of less back office work and more automatic sales.

ADS acknowledged that an AFC system was technically feasible and the problem in London was that it had to be overlaid on an existing system that was not designed for AFC in terms of existing ticketing or station layout. A cautious approach was suggested, starting off with an experimental installation at one station and expanding to a complete installation at two stations. If successful this would be expanded to an interim system across the network, a process that was expected to take some years. This would have to accommodate manual checking of tickets at some stations and automatic checking at others, which would inhibit the level of innovation possible. Once all stations had received all the automatic equipment then it would be possible upgrade to a 'final' system that would deliver all the advantages that AFC offered.

ADS made a technical distinction between the automatic ticket barriers that would be required and the apparatus needed to check the coding electronically, which apparatus they term a 'Farator'. It was proposed to install a barrier and Farator at an outlying station where passenger reaction could be gauged and equipment performance tested. If successful a busier station would also be equipped, this time with prototype ticket machines and other equipment. For these early tests it was hoped to adapt existing ticket issuing equipment to apply a magnetic ink code to ordinary tickets but to issue pre-printed and pre-encoded tickets from ticket offices for anything else; these would also use magnetic ink.

The report states that in parallel with these experiments a new kind of ticket would be developed with a magnetic oxide surface on the reverse side. The reason for this was that although there was confidence that magnetic ink would be satisfactory for seasons and single-use tickets it was not possible for the coding to be altered after such tickets had been issued. ADS conceived that part of the justification for AFC would be the development of stored value tickets for use in the final scheme and this required a ticket where the coding could be re-written, and this was not possible with ink. This seems to have been the first suggestion by anyone that a magnetic surface, where the code could be carried unseen, should be used and of course it is what nearly all 'paper' tickets later came to use all around the world.

ADS noted that LT had suggested Stamford Brook or Ravenscourt Park might be used for these early tests. This would require a range of other stations to issue either ink or magnetic tickets where issued to these stations (which is more or less what was done). Evidently this had been discussed with Robert Dell who had indicated that he could not only arrange for the necessary printing plates to be supplied to the stations concerned but that he could also arrange for a magnetic ink to be used. For season ticket holders from BR stations it was hoped to issue them with a coded ticket for the LT portion of the journey for the test period. Hammersmith was mooted as a convenient and rather busier station for the second stage of the experiment.

ADS was very keen to try out a plastic-based magnetic ticket on a stored fare basis and which would be retrieved when its value reduced to zero. The passenger, if required, could then by a new ticket with value attached. One reason was the cost of card stock tickets which, so ADS was told, cost over 5/- a thousand for 'roll' stock printed at time of issue, to 7/6 a hundred for pre-printed card stock. With well over a million tickets sold every day the idea of a re-useable ticket looked as though it could save a lot of money. ADS did not want station of issue or value to be printed on the plastic tickets and thought giving passengers a separate receipt should be the way forward.

It was suggested that one or both of the experimental stations could also test a new design of ticket machine that appeared to be necessary for full AFC later, but details had not been worked up. It might be possible to use the new design to issue an experimental stored value ticket on magnetic (and perhaps plastic) stock.

The long term aim was to introduce an AFC system that used three different ticket types. These would be one-ride, stored fare and route code. One-ride tickets would be equivalent to the existing ordinary tickets issued on a station-of-origin basis. Stored fare tickets could be used anywhere and for a number of journeys and the value of the actual journeys made would be deducted from the pre-paid 'fare' stored on the ticket. Route code tickets could be used for unlimited travel across the network, or on particular routes or in particular areas and could be time limited; they had a variety of uses and would be used to replace season tickets, passes and rovers.

For the interim system the situation was more complicated. One-ride tickets would be like existing station of origin tickets but with a magnetic ink code at manual stations and magnetic oxide code at automatic stations. It would not be possible to put a date code on the ink tickets but it was suggested the oxide tickets could be dated on entry and date checked on exit; the means of dating oxide tickets was geared to the objective one day of having stored fare tickets which could not be pre-dated. Return tickets would require separate forward 'half' and return 'half' tickets to be issued, the return half being available to the station of issue from any station within the area the fare allowed.

Stored fare tickets would not be feasible during the interim period as they could only be used where equipment was provided. ADS thought it technically feasible (though complicated) to maintain the existing system of season tickets available for unlimited travel along specific routes and with intermediate station availability. Other options were possible but ADS didn't seem to be getting much encouragement to offer anything too radical at this stage. Stored fare might replace seasons one day, but route code tickets would still be required for passes and rovers.

Route code tickets were expected to carry a route code that related to a prearranged set of stations, for example in an area or along a line of route; this was intended to simplify the number of stations that had to be checked in the equipment's database. Each station might have its own set of valid route codes loaded on its system and if the relevant code were not in the database the gate would not open. Nevertheless it was seen that this could give rise to excessive complexity of extended across the whole of the system and was only proposed for the central area. Beyond this area, where there were only branch lines with one possible route, it was proposed to add the station of origin and a fare code to the value of the point where the route code took over. This was a mere device to find a pragmatic way of dealing with an exceedingly complicated challenge. The station equipment at outlying stations would recognize the ticket as a season or pass and treat it accordingly, returning it to the passenger

after use. However, there was another complication in that stations beyond the intended validity might also accept the ticket up to the fare coded on it. The suggestion was to encode some kind of direction indicator so that (for example) a route code ticket issued at Hendon Central for (say) Chancery Lane and bearing a fare covering stations to Euston, would be coded with a 'south' discriminator so that it would not be accepted at stations towards Edgware. Already we can see some of the challenges that season tickets were to cause later and it was acknowledged that the proposals were complex and would create anomalies.

Recognizing that the matter of excess fares was a thorny issue subject to a range of weaknesses, a combination of proposals was suggested. For those who arrived at a destination with no ticket a penalty was suggested as there appeared to be no good reason why they should not have a ticket, especially as more (or all) stations would be gated. For those who, for some reason, had a proper entry ticket but who genuinely had an excess to pay the important thing was to account correctly for the cash taken; one obvious reason would be for a stored fare ticket used for a journey for which there was insufficient credit on the ticket. The suggestion was a special excess fare machine to be provided for use by someone whose ticket had been rejected at exit. The failed ticket would be inserted into the excess fare machine which would establish what fare had actually been paid and calculate the difference. An excess fare ticket would then be issued and the existing ticket captured. This apparatus was not without technical difficulty but such was the level of cash lost that it was felt an idea that should be more closely examined.

From a technical point of view it was intended to store about 500 station of origin codes at each station, each mapped to the specific fare due at that station. It had already been accepted that whatever ticket type was involved, only the appropriate adult single fare would be coded on the ticket, much simplifying the problem of checking validity. For a route code ticket, the same 500 codes were available but would be used differently; each code would simply indicate open a gate or leave it closed and would therefore relate to what was encoded on the ticket as its 'route'. Certain of these codes could be used for (for example) staff passes and where necessary could override any check on date or other restriction.

Although all tickets would be coded with adult fares, children's tickets would be encoded with a 'child' indicator, the intention of which was to illuminate a sign at the gate, marked child, so that staff had an opportunity to challenge an adult using such a ticket.

At each station it was proposed that the fare tables and other data needed to decode a ticket be stored on a magnetic drum memory unit. These were an established means of data storage in those days and had been found to be fairly reliable. They were also very quick in operation. The concept involved reading the ticket and transferring the code to the drum and then performing the necessary logical operations required. If necessary an updated code could be created on the drum and then rewritten to the ticket. At this stage neither the coding format of the ticket or the exact nature of the storage architecture on the drum had been formulated. Nevertheless it was postulated that tickets would need to carry coding relating to ticket type, date, station of origin and fare, with the same fields used on route code tickets for route code and expiry information. Tickets might also contain 'last use' information if not implied from other data (eg to open only an exit gate if last use indicated entry). In essence, once all the ticket information had been loaded to a drum a series of logic circuits would compare the relevant coding against a series of tables and if co-incidence were found with a valid combination of station, date, fare, route or other factor then the relevant gate would open.

Owing to the speed at which the Drum memory operated, it would be possible for one of these to service a number of Farators and associated ticket gates, greatly reducing cost. For the whole of the system the need for 1056 automatic barriers and Farators was postulated, with 314 drum memories 248 excess fare machines, 956 change giving machines 1912 sets of ticket vending equipment and 314 stand-alone ticket encoders for the clerk to use where some kind of special ticket was needed for which stock was not held.

There was some discussion about the design of ticket gates, ADS having some experience of rather large gates suggested for Los Angeles that were

effectively person-height. For the London report, turnstiles were looked at as being cheap and reliable. The down side was that they were reputed to be easy to cheat and some people really disliked them, a feature more obvious amongst the British, apparently.

If turnstiles were out, an 'open gate' barrier was suggested. In its preferred form it would close after each passenger and only open when a correct ticket were inserted. A recommended refinement was to allow the gate to remain open if a second passenger inserted a correct ticket before the first passenger had finished going through, and this would require a counting mechanism; the advantage was that it would speed up the flow. A wrong ticket would cause the gate to close in front of the person who had inserted it. Though hard to get all this tuned perfectly, it was felt a goal to aim for. ADS felt that London Transport should develop its own design of gate to meet its own particular circumstances.

ADS suggested a development programme that expected systemwide installation to take place at all 228 stations over four years between 1967 and 1970 at an overall programme cost of £5.5 million. This hinged upon the successful development of a suitable ticket reader, fare computer and ticket barrier design, upon which, it was urged, work should start immediately.

Appendix 2
Technical Aspects of the Victoria Line AFC System

The Victoria Line AFC system relied on a technology using elementary logic devices—principally junction diodes, supplemented by transistors performing either amplification roles or used in pairs to form simple memory devices. These memory devices (called bistables or flip-flops) memorised the last electronic bit it was given until it was deliberately cleared; by this means inputs and output could be stored for long enough to be further processed. Bistables could be banked together to memorise a sequence of bits, and such a bank was called a register. Modern computers employ these devices in enormous numbers and many millions can now be fitted to a small computer chip. In Victoria Line days, there may have been 30 or so registers and maybe a hundred bistables, all formed of individually soldered components, and this lot would have occupied at least one whole equipment rack and later on an entire bank of them.

This early equipment was only programmable in the most tenuous sense, and could only accommodate serious changes in function by altering the hard wiring. It was essentially a series of devices designed to check certain conditions were met whenever a ticket was presented, and if they were then a ticket gate was opened. The conditions were that a ticket was within date, of a type logically correct for use when and where presented, and, for certain tickets, that the correct fare had been paid. Once the system had been designed it was very difficult to alter the logical checking that took place. An inevitable consequence of this was that once the logical system of checking had been devised and installed, it became difficult to change the ticket system.

The first problem was to read and store the ticket code so it was available for processing. We have seen in the main text that magnetic ink was tried but the magnetic signal was weak and reading was very unreliable, so coding on a magnetic substrate on the back of the ticket was the system eventually used.

After trials of several different kinds of ticket transporter the Victoria Line system employed a rotary design where a large diameter wheel rotated behind the ticket insert slot around part of which was a tight rubber band. When a ticket was inserted it was snatched at the point where the band met the wheel and conveyed around the periphery of the wheel by about a third of its circumference. At the end, guides detached the ticket from the wheel and the band ejected it via the exit slot (at exit gates a moveable guide could divert the ticket to a collection bin instead). The wheel was much narrower than the ticket and this left room either side for two pairs of reading heads, one pair above and the other below the ticket so that both code tracks could be read whichever way up the ticket was inserted. The speed at which the ticket passed the heads was 68 inches a second, which represented a code reading speed of about 1kHz, for which the circuit design was optimized. The heads were cross wired one pair in parallel with the other so that it did not matter which way up the ticket was inserted.

The actual code comprised 29 code bars to describe the ticket properties and two extra bars (one at each end) on one of the tracks which acted as direction discriminators; the code positions were numbered 1-31 for descriptive purposes. The track with the direction discriminator was (arbitrarily) called the bottom track and the other one the top track. The ternary code was arranged such that a bar on the bottom track represented ternary 0, a bar on the top track represented ternary 1 whilst a bar on both tracks represented a ternary 2. This arrangement meant a simple logic circuit could detect where a code position was located and use this as a clock to load up the 31 register positions as the ticket progressed. To cope with the fact a ticket could be inserted either way round it was actually necessary to provide four registers. One pair was loaded up from one end whilst the other was simultaneously loaded up from the other end. By detecting which pair had the code discriminators in their correct position it was now discovered which way round the ticket had been inserted, and hence which pair of registers to use for further processing.

The processing did not take place at the gates, which would have been a very extravagant use of equipment and in any case there was insufficient

space. All the calculations required were undertaken by what was termed the station calculator, which was a series of hard wired racks occupying a whole room. Fortunately the logic systems were extremely fast and it was possible to have only the one calculator on a station, each capable of serving up to 15 gates using time division multiplexing. This, at least, helped keep costs and complexity within plausible bounds. Once a ticket had passed the logic tests the instruction was sent back to open the corresponding gate. Generally a failed ticket simply produced no gate response and the ticket was rejected. A limited amount of additional information was passed back to the gates when an acceptable ticket was read. Firstly an instruction to divert a ticket to a capture bin where it appeared there was no further legitimate use for that ticket and another to illuminate a 'child' sign at the gate where a child code had been detected to make it obvious when a passenger was claiming to be a child.

Once the 29 'useful' bits were transferred to the station calculator a succession of logic checks took place simultaneously. It will be helpful to describe the various code groups coded on the back of the tickets to indicate what information they held.

Group	Bits	Avail codes	Use Ord (day tickets)	Use Season
A	7	2186	Station of Origin	Station of Origin
B	7	2186	Ticket type	Station of Destination
C	3	26	Not allocated	Expiry Year
D	4	80	Shillings paid	Route
E	4	80	Pennies paid	Expiry Months
F	4	80	Expiry day	Expiry day

Ordinary tickets

Taking ordinary tickets first, the calculator had to inspect each of the sections of code and make logical comparisons to determine whether a ticket was valid or not. The top and bottom track registers for each separate code group were connected to matrices of diodes designed to give a positive signal at one and only one output per group, each of these outputs representing a single decimal number (for some groups there were a large number of possible outputs). Group A (code positions 2-8) represented the station of origin. All stations served by Underground trains were allocated an arbitrary number which, from inspection, appear to have been allocated in alphabetical order, with allowance made for new lines and stations that were anticipated, including Lewisham, Ludgate Hill and London Airport. Oddly, although Pimlico is correctly positioned, Brixton and Vauxhall have been added at the end, out of sequence. For group A there were 350 outlets though only 300 were used and just one output was produced by a correctly coded ticket, this representing the station of origin. Stations were numbered upwards from 1 and appear to have reached 282 with some higher numbered spares available.

On an entry gate the station indicated by group A was compared with the number allocated to that station and required a match, or the ticket was rejected. The next field was to ascertain the ticket type, and at an entry gate this had to coincide with one of the codes acceptable at an entry gate (for example adult single). Ticket types were identified in group B and were numbered 300 upwards to differentiate them from station codes (which would be found here if the ticket were a season). Code 300 was an adult single, for example, and 301 a child single.

For most tickets the fare paid was not an issue at an entry gate and the only other check was for the date, set out in group F. It was considered impractical to deploy a unique date and the arrangement was to use the codes 1-31 for days occurring in odd months and 32-62 for even months, the whole forming a 2-month cycle; this was felt adequate to discourage fraud. The date code read from the ticket was compared with the actual date which was set each day at the station by means of a large 62-position switch. Because new stations being equipped for AFC might not have date switches at first, a master code (64) was also allowed for and the logic circuits accepted this on any day. Generally, then,

an entry gate would accept a ticket of the correct type, on the correct day, at the station of issue.

The real fun started at the exit gate. Here it was necessary to establish the correct fare had been paid. The station matrix reported the station of origin from group A and passed this to the fares field and at the same time the fare paid was established in shillings and pence (from groups D and E) and this was also passed to the fares field. The fares field was a hard-wired board where by means of cross-connections using large numbers of diodes, every station was associated with one and only one fare. The logic circuits had to determine whether the actual fare paid equalled or exceeded the fare required in the fare field and returned an indication if this was true. Providing the ticket type was appropriate for the fare paid (for example, it was an adult single ticket), and provided the date was correct, the gate would open and the ticket would (with certain exceptions), be captured.

The fare paid coding was designed in pre-decimal days and appears to have allowed for a combination of shillings and pence up to quite high possible fares, which would have allowed for expansion of through journeys to British Rail destinations in London. Upon decimalization the challenge was how best to alter the coding. It was eventually determined to abandon altogether the use of pence in group E, and redenominate the shillings area (group D) into units of sixpence, in old money; this was equivalent to 2½ new pence in the new system and as the old sixpence was to be kept in circulation for at least two years and was the smallest silver coin this was regarded as fairly future proof as it would not matter if that coin disappeared and only 5p fare steps became the norm. It suited the run up to conversion where quite a few fares were 6d or rose in 6d steps. In fact after conversion, all fares were altered to rise in 5p steps which the new arrangement accommodated, simply incrementing two units for each 5p fare charged. So far as it can be determined child tickets were invariably coded with full adult fares to simplify the calculation required. The child ticket indicator above the gate has already been described.

Return tickets were issued, but as separate tickets. If a return ticket was presented at a gate then the calculator more or less operated in reverse of what has just been described. On entry the correct fare had to be determined to the station of issue while on exit the logic simple looked to see the journey was finishing where the ticket had been issued (but the ticket had to be collected). It was not possible for an entry gate to know to which station a return transaction had been made so in practice a high value return portion would let one in almost anywhere, and similarly a return ticket presented to a correct exit gate would have no way of knowing from where one had actually come.

I have inspected a large number of platform tickets and in every case these were encoded as type 300 tickets, or adult singles. These were only available at ticket offices and would operate entry gates but not the exit gate at the same station where they would have to be presented at a staffed barrier. This would have avoided (for the time being) adding yet further complexity to the processing equipment but had the system been further developed a specific code would have been needed. Excess fare 'tickets' were encoded 332 and this opened the exit gate at the station of issue if date were correct as well.

Period Tickets

There were then weekly and season tickets to contend with. Although these tickets were much longer than ordinary tickets to make them distinctive and to carry the necessary written information on the front, the coding was still constrained within the ordinary 29 code bars available for the purpose. As a matter of policy, London Transport felt it necessary to maintain the same availability for AFC period tickets as normal period tickets. In other words, between particular dates they allowed unlimited travel by one route only between defined stations, but could be used at intermediate stations. This was a ferociously difficult technical problem without the use of computers. The way this was tackled was to use the group A (station of origin) section of coding to represent one terminal station and group B for the destination terminal station. This was straightforward as stations were numbered below 300 while day ticket types (which also used this group) were numbered 300 or higher.

From this, it will be seen that a period ticket presented at any station offered two station codes and no ticket type code, immediately indicating it was a period ticket. If either station code was found to match the station at which presented the journey was considered acceptable. This meant the station calculator had to incorporate a second station matrix, which much-increased complexity.

To handle intermediate stations it was necessary for the equipment to determine whether the station at which presented was on the line of route between the defined terminal stations, but how on earth could it do that in the pre-computer age? It took LT engineers two years to think of a way of doing this. The first challenge was to determine what was a possible route. This was done by determining, for every station on the system, which other stations were, quite arbitrarily, to its left or to its right. A feed was taken from the station outputs to logic units, each called a 'station box'. Left hand stations went to a left hand station box and right hand stations to a right hand station box. Each box was in essence a large 'or' gate and would produce a single output if any input were identified. On simple parts of the system, such as branch lines, most stations would be in one box and a handful in the other and provided an output was received from each box then the ticket must lie on the line of route.

Matters got more interesting in central London because multiple routes were possible. It was therefore necessary to provide additional pairs of station boxes for each possible additional route. The wiring would be similar between one pair and another but certain stations would be in a left hand box rather than a right hand one, or vice versa. Provided that at the station where a ticket was presented there was at least one pair of boxes where one terminal station was in one station box and the other station in the corresponding box then a route was possible. Small stations often had only one pair of station boxes, central area stations often three or four, but a few awkward places had larger numbers (one station had seventeen pairs).

To determine whether the possible route was valid it was now necessary to examine the route code. Each pair of station boxes produced an output corresponding to a decimal number (ie one, or possibly more, of ten outputs was indicated when a pairing was identified and this had to correspond with the route code actually encoded on the ticket. If coincidence was achieved then the ticket was valid at that intermediate station. Although the ticket office equipment used the numbers 1-10 the actual codes imprinted in field D were in the early 20s, keeping them in a separate range from the fare.

Since a ticket had to work at any valid intermediate station it was necessary to ensure that whatever route code was encoded on a ticket would correspond with the same code employed at associated station boxes at every station along every possible route. This was easy where stations were close but must have been a headache in some instances. The technical descriptions indicate that route codes were allocated numerically starting at the left-most possible route, not a surprise as signal engineers numbered everything from the left. Naturally it could not be left to booking clerks to guess at probable route codes so each ticket office had a code book listing the station numbers of all possible destination stations, the valid routings and the relevant route codes. All this had to be entered into the season ticket encoder when a ticket was issued.

To reduce the technical complexity of what was by now already a very complex arrangement the engineers realized that since a ticket from A to B had the same validity as one from B to A it was very wasteful and complicated to allow both options to exist. From a technical point of view it was much better always to have certain stations at one end of a journey and other stations at the other end. As designed, the station of origin (ie station of issue) always occupied code group A on the tickets, and the destination station of seasons was intended to occupy group B. However to allow for the technical simplification just described it was sometimes necessary for these positions to be reversed. The season ticket encoder therefore included a Local/Distant switch; when set to Local the stations were in the normal order but when set to Distant the location of the two terminal stations was swapped. Instructions about operation of the switch were also included in the season ticket code book and gave the booking clerk a further opportunity to make an error! Issuing an AFC season was not straightforward. By way of example the ticket coding for

Victoria Line routes always denoted the southernmost station as the station of origin irrespective of where the ticket had been issued.

Matters were further complicated by the existence of cover points. These were stations beyond that asked for where the fare was the same; to reduce ticket stock period tickets were issued to the cover point, which was not necessarily the station asked for. This had a bearing on possible routing. And so it went on. It was inevitable that mistakes would be made in coding AFC tickets and that it would take longer than for an ordinary season. Bearing in mind also that all this had to be hard wired, this was immensely complicated to arrange. One wring error, component failure (or just one imperfectly soldered joint) and it wouldn't work properly.

It is now necessary to look at the way period tickets were dated, which was another nightmare given the range of tickets on issue. It appears from old AFC wiring plans that the expiry date of a season ticket would be established from a combination of day (group F), Month (group E) and Year (group C) coding. The year coding could accommodate a maximum of 26 variations but a 1970 drawing shows 20 individual year codes covering the years 1971 to 1990, which was presumably considered sufficient to deter fraudulent reuse. Examination of a large number of early season tickets suggests the year code block was never actually used. The months codes appear simply to have been the months (1-12), recast into a block higher than that used for the pennies element of the ticket price (the codes 13-24 was intended to be used for the months). The date code has already been explained and from examination of old season tickets the same odd and even month blocks were used for the days that were deployed on the daily tickets.

This is not the system deployed though and, presumably because it was simpler, by 1970 seasons were coded in 2-yearly blocks of month codes (the codes 13-36 being used). In odd years the months took the block 13-24 and in even years the block 25-36. There was no change to the day code. A passenger who had hung onto an old season would have to wait at least a year before it was usable again, and then only if they understood the coding.

When a season was used, the coding was cross checked with the month code set at the station, which was set by means of a board with 24 sockets around the periphery labelled 1-12 (odd years) and 1-12 (even years). There was a wander lead associated with this board, and it had a plug on the end. This wander lead had to be inserted in the socket for the current month (in the odd or even year as appropriate). There were a further 11 plugs (without wander leads) which had to be inserted in the 11 sockets preceding the plug with a wander lead. Coincidence between the month code on the ticket that was being presented, and any of the months where there was a plug inserted in the station calculator room, meant the month code presented had to relate to the previous 12 months and no farther back, reducing chance of an of ticket being recycled. The actual expiry date check merely had to ensure month code on ticket was not higher than that on station. The day of expiry was also coded on the ticket and used the same day coding block used on ordinary tickets. Because seasons were period tickets a simple comparison with the day code set at the station was insufficient and the logic circuits had to check that the ticket was being used up to that date but not after (whilst an ordinary ticket could only be used on the stated date). This was tricky and the reality was that it was only necessary to check the day code in the actual month of expiry. Seasons were available for any period up to a year and the 2-year cycle meant this fairly crude method of coding was sufficient.

There is circumstantial evidence that weekly tickets were added to the system as an afterthought. Weeklies could have used season ticket coding but for one important feature. They had to be available from Friday evening to end of traffic following Saturday and the overlapping of days was a problem overcome by the use of week codes. The week code on the ticket had to match that set at the station at which presented. The station code was set by a plug board with a plug stuck in the hole for the relevant week. To cope with the weekend overlap, a second plug was provided which was stuck into the adjacent week's plug hole until Sunday morning when it was removed. Coincidence with either was good enough for validity to be accepted, but it is hard to believe staff would not sometimes forget to get this right. The week code itself was

portrayed by the decimal numbers 1-52, which were the numbers used on the plug board. The coding was split between the date zone and the pence zone (used for months with seasons), the latter handling the first digit of the week and the former the second digit. So the logic circuits realized this was a weekly and not a season the numbers actually used were in the range 40-45 for the week first digit and 70-79 for the week second digit (so, for example, week 32 would be coded 43-72).

One can see from all this that the circuitry was very complex and very difficult to change. Given that none of the present tickets that are available conform to those around when Victoria Line opened, the widespread adoption of the AFC system would have been found something of a hindrance. Consider even a simple fares change. At each station the fares code board had to be physically changed with a replacement that had been hard wired with the new fares. Even a minor change would have required the whole board changing. Imagine that had we seen full AFC at every station.

Reliability and freedom from mistakes of a system such as this must have been very difficult. Tickets in the author's collection include several for long journeys that were only coded as far as a Victoria Line interchange station and not to final destination. Many of the earlier Hammersmith seasons were only coded for Hammersmith and could not have been used anywhere else. This suggests that acceptability at intermediate stations and various other aspects of season ticket coding had proved challenging, and not always was this confined to the more complex journeys.

Appendix 3 (Part 1)
'Plan A' – Automatic Fare Collection on London Buses

Introduction

The development of smartcard ticketing on buses, and its integration with London Underground smartcard development, has already been covered in the main text. But automatic fare collection had already been attempted on buses during the 1960s and 70s and it is convenient to record what happened in this appendix, which sets out the heroic efforts to find a workable system at a time when the prevailing technology struggled (and ultimately failed) to meet the requirement. The quest was to reduce boarding times on front entrance, one-person operation (OPO) vehicles by collecting some or all fares using automatic equipment, a real challenge with the pay-by-distance fares then in operation.

Most of the London bus fleet has traditionally comprised double deck buses with a conductor collecting the fares and issuing tickets that were either pre-printed or printed on the spot by a machine. On less heavily used routes, or where there were low bridges, single deck vehicles might be used, but these still had a conductor and this was increasingly felt wasteful because of the lower loadings. So far as post-war efforts to reduce costs are concerned, four trial suburban routes were converted to one-person operation (OPO) in November 1964 when the front-entrance single deck 'RF' buses running on them were equipped with doors and the driver collected fares and issued tickets. No level of automation was installed and a ticket machine was simply mounted on the side of the driver's compartment and passengers paid the driver and collected a ticket as they went past. Remaining 'RF' vehicles were converted later.

London Transport had until the mid-1960s preferred its own design of vehicles, to meet what were claimed to be the unique conditions of London. It became desirable to compare London's own vehicles with standard commercial front-entrance double-deck buses. An experiment began, from November 1965, using a small fleet of Leyland Atlanteans with power-operated doors at the front of the vehicle, controlled by the driver (who was best place to monitor their operation).

The purpose of the experiment was to test the operation of the vehicle as a whole and not to alter the arrangement for collecting fares. It was hoped that with the driver supervising boarding and alighting the conductor would be able to spend more time collecting fares and preventing over-riding.

The background to Automatic Fare Collection

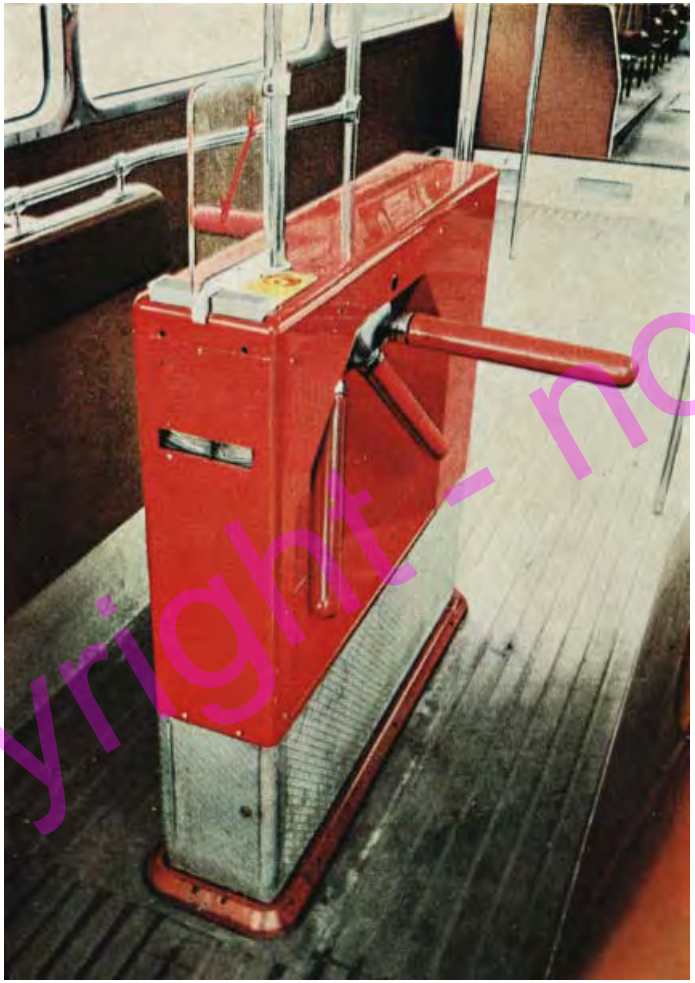
By 1965 the difficulty in recruiting staff, the high cost of staff and the suspicion that for some services, at least, the use of front-doored buses would be necessary, invited thoughts to turn to the possibility of automating fare collection methods so that OPO operation would be possible. It was hoped that the public service vehicle (PSV) regulations would be relaxed to allow OPO operation. At the time, the regulations required double-deck buses to carry a conductor irrespective of boarding arrangements. In fact these regulations were altered in 1967 so that on certain routes conductors could be dispensed with on double deck services; later relaxation eventually allowed any service to be operated without a conductor.

The situation is aptly described in London Transport's 1965 annual report:

> The one most significant factor in the cost of bus operations is the high labour cost, which arises from the necessity at present, inherent in the use of a graduated fare system, of using two men on each bus; while this requirement persists only marginal improvements in the productivity of the bus staff can be secured. The Board are considering the practicability of introducing an automatic fare system for the buses, and research and experiment in this field is being undertaken as a matter of first priority. It is only by means such as this that a significant change in the economics of bus operation can be secured.

Early Automatic – Red Arrow Flat Fare Turnstiles

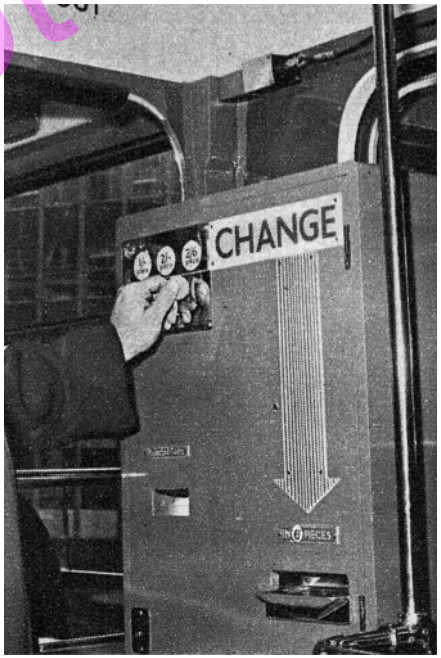
The first bus route to accommodate automated fare collection was the newly-introduced Red Arrow limited-stop service, route 500, from April 1966. These used experimental Merlin vehicles and were described as 'standee' buses, as there were only seats at the rear, and forward of the centre doors people were expected to stand for the short distance they were likely to be travelling. No conductors were to be provided. These were the first of what were to be a large number of high-capacity single deck vehicles and special dispensation was given to avoid need for a conductor, who would have found it difficult to operate in such surroundings.



A pair of turnstile entry gates on a Red Arrow bus viewed from vehicle entrance. The 6d fare was inserted in slot at front of corresponding gate.

Inboard of the leading door, passengers were split into two streams with a turnstile installed for each stream. Upon inserting a sixpenny piece in a slot in the stanchion dividing the two flows, the corresponding tripod barrier was released allowing entry, but no ticket was issued (it was a flat fare throughout, despite the legal complications this created at the time). An on-board change machine was installed on each bus to change shillings, florins and half-crowns to sixpences, though reports at the time suggest these machines were not found very reliable and they were withdrawn in 1969. The use of the turnstile by passengers was simple enough, and generally quick once passengers worked out how the system operated. Although the equipment when properly adjusted was fairly reliable there was no return coin arrangement and a bent coin could create a problem.

The idea of pay-on-entry turnstiles was extended to the other Red Arrow services when introduced two years later (these used different vehicles, the MBAs, but the layout was similar).



(Above) View along the new red arrow bus showing the two turnstile channels.

(Left) A Red Arrow change machine, installed just behind driver, ahead of the turnstiles.

Early Automatic – Suburban Flat Fare Turnstiles

Serious unremitting staff shortage and consequential bus unreliability caused LT to consider recasting bus services in London with shorter routes and widespread introduction of OPO using new single deck vehicles, particularly in suburban areas. The policy was set out in a document called 'Reshaping London's Bus Services' in September 1966. There was some delay in bringing this forward but widespread changes began to be made from September 1968. Many of the revised suburban routes were relatively short and adopted flat fare operation using another variant (the MBS) of the high capacity single-deck Merlin buses fitted with coin-operated turnstiles. For the 1968 changes the intent was that all fares be collected by machine and while a twin turnstile solution was again provided the equipment was entirely different from that used on the red arrows as a wider range of coins was wanted and the ability to have a separate fare for children (no child fare was available on the Red Arrows).

The coin acceptor/gate controller installed on the Merlin flat-fare suburban routes was developed by Setright Registers Ltd to an LT specification and could accept 3d, 6d and 1/- coins, all inserted in the same slot and counted inside the equipment, which could be adjusted to accept any fare between 3d and 7/9 in 3d steps. These machines were designed to be convertible to decimal currency and comprised large metal boxes mounted opposite the turnstiles on flat surfaces next to the nearside and offside windows, over the wheel arches. The actual turnstiles were similar to the Red Arrows and were mounted off a central stanchion dividing the two flows. On inserting coins totalling the correct fare an 'enter' sign illuminated and the gate was released, but no change could be given. To accommodate passengers without the right money, drivers were able to give change before passengers approached the machines, but passengers were not encouraged to do this unless unavoidable.

The publicity material at the time explained that one machine of the pair could accept a special type of pre-printed ticket (described as 'forge-proof') which was accepted upon insertion, with a small piece cut off until the total number of journeys had been made, when it was no longer usable; these tickets were to be available mainly to school children. A total of ten journeys was the expectation for these tickets but single journey versions were also intended to be available. Despite the hype these tickets, though printed, were never actually introduced. The slot for validating them is just visible in the photo of the machine.

In ordinary use a children's fare was available by simply pressing a 'Child' button, which sounded an alarm so the driver could check who was using the machine. The driver also had the ability to release gates to allow pass-holders (eg staff) to board free.

The new system was introduced in the Turnpike Lane and Wood Green areas from 7th September 1968, the same day as the new Red Arrow services also began. The Wood Green scheme was the first 'area' scheme to be introduced, based on an area hub with relatively short flat fare routes radiating therefrom. These routes were chracterized by lettered prefixes, W in this case, covering new routes W1-W6 using 44 new MBS vehicles. In addition new route W21 was also introduced the same day, based on Walthamstow but using the same vehicles and equipment. In each case the adult flat fare was sixpence on these seven routes but while new single deckers also entered service on nearby conventional routes all tickets on those were issued by drivers.

The introduction of successive swathes of flat fare routes in the suburbs rarely began well but the immediate reaction to this first but huge upheaval must have been dispiriting for the staff involved as well as frustrating for the passengers. The fare collection equipment was heavily implicated in increasing boarding times through unfamiliarity and the longer (and often wider) vehicles were sometimes more difficult to manoeuvre through congested streets and it was often quite difficult to pull into bus stops correctly owing to nearby parking. Buses were also found very unreliable and often broke down during their journey (if they made it into service in the first place); the fact of their having been parked 'dead' for months on end before entry to service, owing to union 'difficulties' had not helped. Nor had the staff shortage been fixed so

buses were still being cancelled because no driver was available: Wood Green garage was then 14 per cent below drivers required.

All these made keeping the service regular (let alone to schedule) difficult and although services usually settled down eventually, schedules were more extended and it cannot be said the new arrangements were received by passengers with much enthusiasm. Another problem was change, and imposing on passengers the need to have appropriate coins was irksome. Drivers did have a limited amount of change but a couple of notes might clear them out and increasingly aggressive publicity demanded passengers bring the correct money. One measure, from March 1969, was to place small symbols on the front of the flat fare buses to indicate they had coin-operated turnstiles, to distinguish them from a number of precisely similar-looking vehicles where the driver issued tickets. These symbols also appeared on the Red Arrow services. Public reaction was monitored and the AFC equipment was one of the causes of complaint, though by no means the most strident. In particular passengers with luggage or heavy shopping or small children found the gates difficult to use London Transport knew full well that there was (sometimes well-founded) passenger resistance to the new buses and their fare collection methods, which was disappointing when passenger usage was already falling away. It was a choice between this kind of bus, or no bus.

This type of equipment was also used on the A1 airport express bus introduced in August 1969 but with a flat fare of a shilling.

(Above) The arrangement of turnstile gates and ticket machines on one of the Merlin MBS-type buses deployed among the suburban flat fare routes. There was another ticket machine (out of view here) on the right hand balustrading. Note slot intended as card validator.

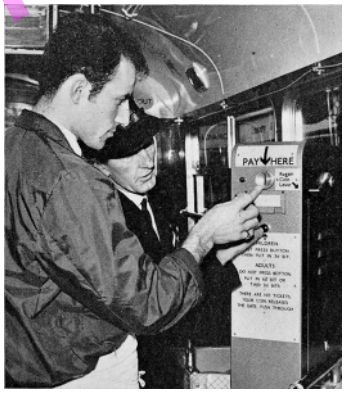
Example of one of the unissued multi-journey tickets intended for these Setrights

This preserved Merlin shows (either side of the headlights) the two white arrow and black coin blob symbols that were deployed on buses with AFC equipment and indicated 'have the correct money ready for the machines'. This distinguished these buses from those which did not have AFC equipment.

Conversion of Red Arrow Equipment

The Red Arrow type turnstiles were going to be a problem during the forthcoming decimalization of currency and it was decided to use the, by now, standard Setright coin accepters used on the suburban routes and which were able to accept multiple coin denominations. The easiest way of achieving this was to change the vehicles and in September 1969 the existing Red Arrow vehicles were swapped for later versions (also Merlins) that had the Setright equipment fitted. Some of the vehicles were in fact new, whilst others had seen suburban service but had been displaced. The former Red Arrow buses were refurbished with the turnstiles removed and some seating installed in the former standee area and all had re-entered service in suburban areas by the end of 1970. No attempt was made to install the dubious change-giving machines on the replacement vehicles.

As described already, the Setright machines accepted sixpences and threepenny bits, were more reliable and were expected to be easier to convert to decimal currency, which would be required in 1971. The ability to accept two coins allowed fares to be raised to 9d in 1970. When decimalization occurred in February 1971 the decimal fare became 4p and machines were altered to accept 1p and 2p coins (the change was actually made a week after D-day to allow sufficient new coins to enter circulation). This fare proved problematic and in 1972 the machines were altered to accept only 5p coins and the fare was raised to 5p. This largely addressed the change giving problem. In 1975 Red Arrow fares were raised to 10p and the same machines were altered to accept only 10p coins.



On left a Merlin Setright being adjusted, showing machine innards. On right an exterior view showing coin return lever.

The Problem of AFC for Graduated Fare Routes

Automating flat-fare AFC was comparatively easy compared with automating the ordinary pay-by-distance fares that were still needed. In the 1960s it was impossible to contemplate the introduction of flat fares on many—perhaps most—bus routes, some of which were very long. Yet the difficulty and cost of recruiting conductors was appreciable and there was a political undercurrent pushing LT towards standard bus designs or some variant of a standard design that was likely to have a front entrance. LT looked at a modified routemaster with a front entrance (a single example was built) but this design, with its front staircase, was impossible to modify for AFC. A mock up was produced of another double-deck design with a second doorway near the centre, allowing passengers to enter that way and leave via the front doors through either two or three AFC turnstiles. It is not apparent exactly how this would have functioned, but ticket slots in some of the gates perhaps echo the ideas for a stored fared ticket, perhaps joint with the Underground. However, we hear no more of the idea after the mock ups had been inspected, but it is illustrative of the thinking that installing full AFC on buses was going to need a leap of imagination.

The reshaping plan rather glossed over how the graduated fare bus routes would function in the longer term. The plan observes:

> 'Sophisticated and probably expensive equipment, which does not yet exist, must be developed to collect graduated fares and ensure that the passenger pays the correct fare for the journey he takes. This equipment must be reliable, robust, and easily operated. It must work fast enough to ensure that the time spent by the bus at stops is not excessive. The Board are actively developing such equipment. If this development proves to be successful, the way will be opened to 'stored fare' tickets which can be repeatedly used up to a given number of miles both on buses and Underground railways'.

This statement fully recognized that from the perspective of 1966 it did not seem possible to get away from the need for continuing graduated fares on most routes. This did not matter on the busiest routes where the new Routemasters were going to be carrying conductors for some years but on other routes, where OPO buses were necessary, a technical solution was required. The reference to stored fares echoes what the Underground managers were aspiring to and there is evidence of a shared objective here and a small level of discussion. It was, however, another thirty years before a technically harmonized approach was adopted.

The Hounslow Experiment and the Split Entrance Bus

The 1967 annual report refers to AFC development work taking place in advance of the new order for one person operation (OPO) buses arriving shortly in large numbers. Development had to consider the best way of dealing with collecting money on graduated fare routes. In the early days of the new OPO single-deck buses it was easy to focus on the suburban services that could operate a flat fare with only coin operated turnstiles but it became increasingly obvious that at some point OPO operation would have to extend to graduated fare routes where (in the light of experience) boarding times would be quite unacceptable if reliance was only on the driver selling tickets.

From 23rd August 1969 ten Merlin MBS OPO buses began operating in Hounslow as part of a pilot scheme for an entirely new approach, suited to graduated fares buses; routes 110 and 111 were selected for the pilot. On these buses, boarding flows were split into two. The left hand door served a flow that passed the driver who could issue tickets and give change in what by then was the usual way on an OPO graduated fares bus. The right hand entrance took the other flow (separated by a barrier) to a combined turnstile and ticket machine. A passenger would approach the turnstile where at the leading end, on the right hand side, built flush into the turnstile housing, were buttons operating a ticket machine from which tickets at 6d, 1/- or 1/6 could be purchased on insertion of the correct money and selecting the ticket required from one of several large push buttons. A ticket would emerge from a slot near the turnstile and on taking the ticket the turnstile would be released. The spacing of the various components was contrived so that a passenger doing things in the right order would find the turnstile released on reaching it and walk through the equipment almost uninterrupted, so it was hoped.

A potential source of delay was establishing what fare was required, which could be a puzzle to those who were not regulars. As the equipment could only issue a very limited range of tickets the only way the equipment could be deployed meant the existing graduated fares had to be simplified by a process of coarsening so there were rather fewer fare stages but the jumps between them were raised to match convenient coinage without having to give change. There was grumbling from those who lost out because of the process but there was very little option.

These two images clearly show the front entrance arrangements of the first split entrance buses on the Hounslow experiment. The front doors folded to the centre to form a partition (continued inside with a railing) so that having entered the vehicle one was committed to either the driver or the machine. This became a problem if the machine failed to

To avoid use of fare charts, which it was feared looked complicated, an electronic display unit was provided. This had the capacity to display the names of up to 15 fare stages and to the left of the names the corresponding fare. As the bus progressed along its route, the 'spent' fare stages no longer needed to be shown, and some or all of the fares to the remaining stages might alter. The driver was provided with a 'rotary dial' in the cab which was progressively stepped forward or backwards each time a new fare stage was entered, and by means of various simple logic circuits the display panel was correspondingly altered to keep the information up to date (the driver already had to do much the same thing with his own ticket machine each time a new fare stage was entered). Passengers had only to read off the fare due from the display panel and buy the relevant ticket. The display panel itself was of the 'normally dark' type where pre-printed information was painted onto the glass so that it was only visible when back-illuminated by an electric lamp. Naturally, this meant that buses would be confined to the routes for which the panels had been specially prepared and reallocation would

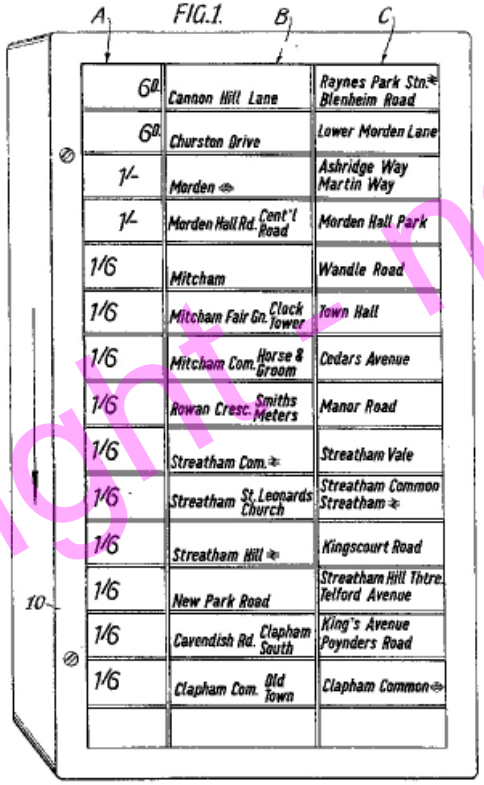
This is rare image of the display panel in use. Despite reflections it is just possible to make out fares in the left column and fairly small fare stage and destination information in the wide column (which actually contains two types of information, see later).

This shows one of the combined automatic ticket machines with integral tripod barrier and fare display panel. The six buttons allow for (right) adult fares of 6d, 1/- and 1/6 and (left) child fares of 3d, 6d and 9d. At front is the coin slot and coin return lever is mounted below.

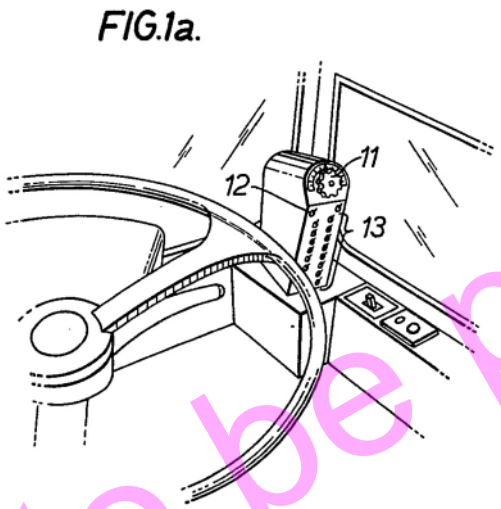
Shown here is one of the Hounslow experimental vehicles 'in use', though obviously staged.

have incurred the expense of moving panels around or having fresh ones prepared.

The display equipment was the subject of British Patent 1262712, applied for on 21st June 1968 and only finally granted on 2nd February 1972. The patent draws attention to a number of practical complications. The most obvious one is that the logic circuits had to know which way the bus was travelling as the fare stage names would be one adrift in one direction compared with the other. Even so the display could not avoid showing the approaching names in order downwards when the bus was going one way and upwards when it was going the other way. Direction was set by a switch but it was also necessary to provide additional switches to cater for short workings of buses where some of the displays needed to be cut out. It will be fairly obvious that once the logic circuits had been hard wired, and display panels produced, changes to route, fare stages or the fares themselves, would have been very troublesome.



Shown here is the drawing of the display panel shown in the patent. Note that the fare stage names (in column B) are all in lower part of display (the directional order reading downwards). When bus changed direction the display was ordered upwards and the fare stage name all appeared in the upper part of display and lower names were extinguished. In right hand column were other important stop names lying intermediately between fare stages.

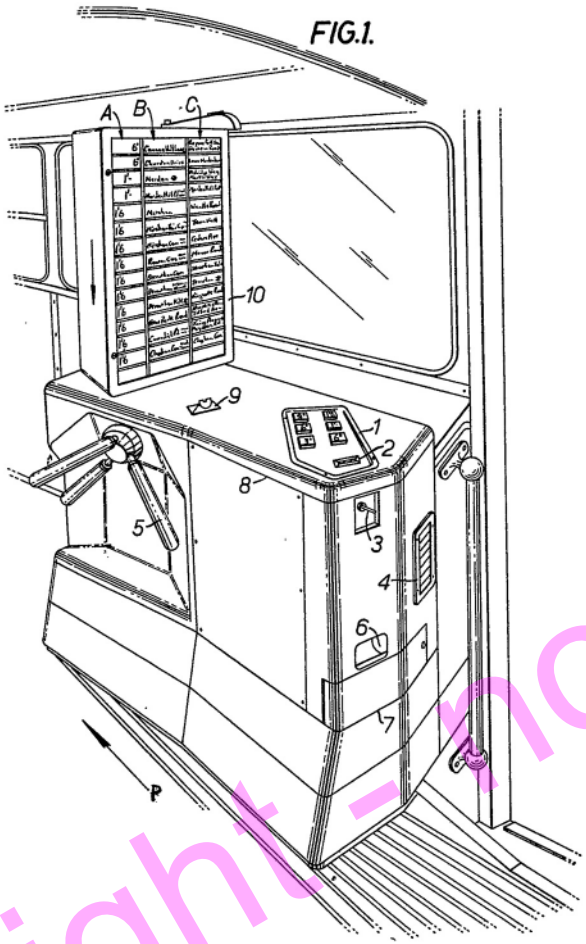


Shown to the right of the steering wheel is the display control box as the patent expected it to look like. The rotary switch with fare stage numbers is at top and the various switches controlling variations required for particular journeys are all underneath.

There was also a separate patent (No 1251975) for the combined ticket selection, ticket printing, coin acceptance and turnstile units assembled into the single cabinet sitting over the front wheel arch. Particular points to note are that the money could be inserted or the ticket selected in either order, the ticket actually needed to be pulled out before the turnstile tripod was unlocked (and it would re-lock when the next arm came into position, and that the fare stage part of the ticket printer unit was operated by, and maintained in step with, the driver's selector switch that operated the display panel. The equipment also kept a tally of how much money had been inserted (no change was given) and how many passengers had passed through. These were indicated on various counters mounted on the front of the cabinet next to the door.

As on the Underground the logic system required to make the display unit function was based on diode-diode logic circuits all hard wired, there were no integrated circuits in those days!

Shown here is the patent drawing of the complete apparatus showing the relative positions of the various parts.



Unfortunately the AFC equipment once more was found unreliable and between January and June 1970 route 110 was withdrawn from the scheme to provide a float of buses for modifications and to cover for casualties on route 111. The experiment having finally proved that this type of AFC equipment could be made to work to supplement the ticket selling facility offered by the driver, the scheme was brought to an end and the buses were reallocated to the Harrow area to help introduce OPO operation in that area on graduated fare routes, the conversion of the 209 used these vehicles from February 1971. The decision was made to withdraw the AFC equipment on the Merlins before decimalization and there is some evidence (which we will turn to) the equipment was reused with modification on new vehicles.

There is no doubt this early AFC equipment was disappointing in service. We must remember that at the time the only equipment available relied on essentially mechanical coin accepting equipment that struggled in the environment of a vibrating vehicle and with old and worn coinage. It must also be born in mind that the camber of the road meant the equipment was not always level and if the bus started before a passenger completed a transaction accelerating forces might disrupt correct operation. The 1971 annual report noted that the reliability of some designs of machine was so poor that on certain routes the equipment was taken out of use and all passengers had to pay the driver. There was also obvious passenger resistance to the use of unfamiliar (and unreliable) equipment and more people chose to be served by the driver than had been hoped. Improvements in reliability later increased usage but anecdotal reports from drivers suggested fewer than a quarter of fares were paid via the machines. Once again, boarding times suffered with consequential impact, but once the commitment had been made to OPO it was important to try and avoid boarding delays caused by ticket-buying and the quest for improvement continued.

Fareboxes

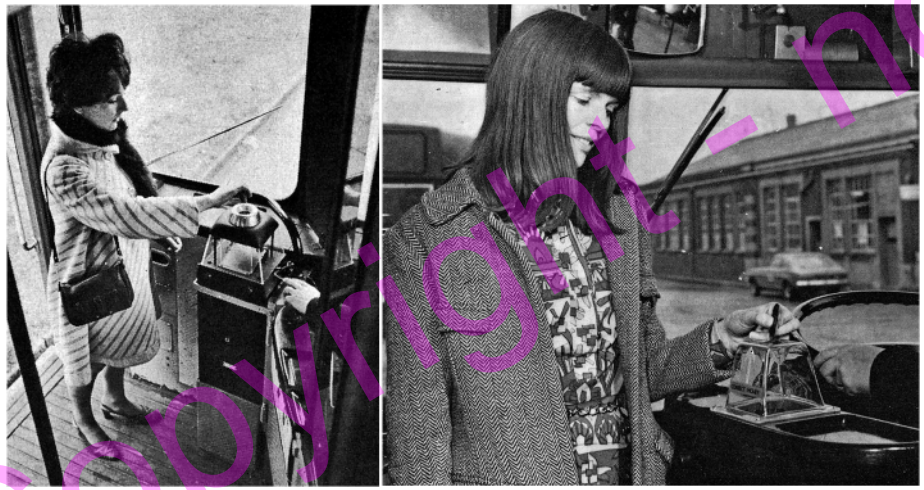
It was in January 1970 that the experimental Atlanteans were redeployed to Croydon and Peckham. As these had front entrances, and the legislation no longer required conductors, it was inevitable that these buses would operate as OPO vehicles. This time a pilot was run using an American idea called the Johnson Box (though often just called farebox. Johnson boxes were not a new idea (they dated to 1911) but it was not until flat fares were used in London that they became an appropriate tool.

The idea was that passengers inserted the correct fare into a slot above a small glass box visible to the driver who could inspect what had been inserted. When satisfied coins were correct he pressed a button or lever releasing the coins into a locked vault below and at same time registering a transaction. At end of shift the driver took the vault to the paying in desk where it was opened

by the clerk, who expected the money to match the recorded transactions. The process was fast for passengers, kept the money secure, and avoided fraud. Previously tested in Manchester, it first came into service in London on new route P3 (formerly 173) where a 6d adult (3d child) flat fare was charged. Not all the Atlanteans were altered to flat-fare farebox operation and some operated on ordinaty routes out of Croydon with drivers issuing tickets in normal way.

Before London Transport decided to install fareboxes in large numbers the American version became unavailable in this country and Sid Haines (the engineer responsible for AFC) designed a similar farebox that could be affixed to the driver's door from where it was more easily viewable and found a British manufacturer to make them. Sometimes called the Haines box, they were used in large numbers.

Tickets were not usually issued where fareboxes were employed (though they could be). For flat fare routes, it was a great deal simpler than the automatic turnstiles. Change giving was possible if the driver had a float and passengers asked for change before any money was inserted into the farebox. Such was the success of the farebox that it was apparent very quickly that, even with a single stream of people boarding, the boarding time compared favourably with the dual boarding turnstiles used on the suburban flat fare routes and was so much simpler. Arrangements were made by the end of 1970 for all the suburban flat fare routes to be converted to fareboxes, avoiding some of the complication of converting machines to decimal currency. Flat fare turnstiles continued in use on Red Arrow routes.



On the left is a Johnson Box fitted to one of the Atlantean buses adapted for one person flat fare operation. On the right is the later Haines farebox, built to an LT specification, after conversion of the AFC suburban Merlins to farebox operation.

Country Versions

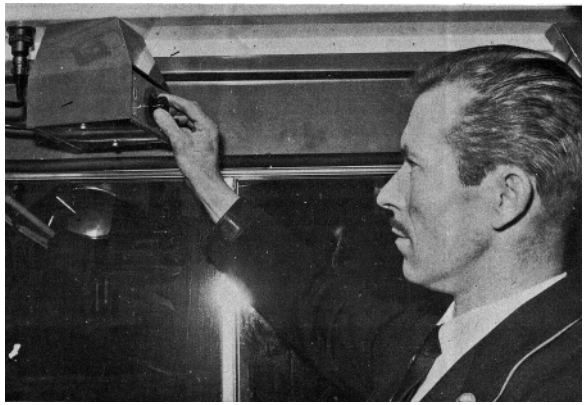
The country bus area was quicker in introducing one person operation, which was generally less of a problem with lighter loadings and longer distances between stops. Quite large numbers of country buses were reduced to one-person operation in 1966, this being possible because many of them were single-deck vehicles. The rear platform double deck vehicles were impossible to convert, even when the legislation changed in 1967, and most of the crew-operated double-deckers disappeared quickly to be replaced by new OPO vehicles, in most cases the new Merlin single deck type which was introduced from 1968 and began to replace older vehicles of all types.

The country bus version of AFC was known as Autofare, and involved passengers looking up the correct fare on a fares list and buying a ticket from an automatic machine, described as an Autoslot Mk IIA machine which was developed by the Bell Punch Co and fitted to some of the Merlins. No turnstiles were used. The system was rather crude. Two machines were installed, one accepting 3d pieces and the other sixpences, a corresponding ticket being issued each time a coin was inserted, and the value paid being pre-printed. Fares were either 6d or 1/-, depending on distance, so for many journeys multiple tickets were required. Children travelled at half fare bus so far as I have ascertained no special tickets were available. These Autoslot machines contained pre-printed ticket paper upon which was impressed information correlating to the passenger boarding point (which was set periodically along the route by the driver). The cash disappeared into a vault at the bottom of the

device which could carry a day's takings and be handed in unopened to the garage each night, an replacement empty vault being installed. This equipment first came into service towards the end of 1968, the first converted route being the 430 between Reigate and Redhill.

On later implementation of Autofare, the situation was different and Mk V Autoslot machines were used. The nearside machine accepted 6d and 1/- coins while the offside machine accepted 3d and 6d coins. Again a ticket was issued whenever a coin was inserted but as only one ticket stock was used the value had to be printed at time of issue. These machines were used fairly widely and suited the higher fares (up to 1/6) that were charged. It was up to the passenger to work out what fare was due and buy one or more tickets to that value. Again the boarding stage was printed at time of issue and in all cases drivers had a modest change float to help make the system workable. The system was not attempted in central London and the equipment was not especially reliable. Upon decimalization Autofare was abandoned as it was not worth altering this dubious equipment (by then services had been transferred to London Country Bus Services Ltd and no longer involved London Transport).

A country area Autofare machine. The fares list shows only two fares in use.



Above are example of Bell Punch Autofare tickets with a stage number overprinted. Below is a driver altering the switch denoting the current fare stage

The Swifts

Early in 1970, the next batch of single deck buses began to arrive. These were built on the Swift chassis and were slightly shorter than the Merlins, though externally the bodywork was superficially similar. There were two variants. One had only a front entrance and all tickets were issued by the driver. The other (the SMS, which we are concerned with here) was a standee variant with a centre exit and front entrance boarding using the 'split entrance' format, described earlier in the description of the Hounslow experiment. On these buses, the AFC equipment was fitted during manufacture and was based upon that used with a degree of success for the Hounslow experiment, with some modifications. The initial batch of standee variants numbered 50 vehicles but successive further batches added another 648.

The first route to be converted to Swift SMS vehicles was route 70 from 18th April 1970. Another early allocation of these buses was for the reorganization of routes in Harrow from 13th June 1970. So far as it can be established from photos, these routes (and probably the whole of the first batch of 50 SMS vehicles) had AFC equipment of similar type to that used on the MBS vehicles involved in the Hounslow experiment; indeed it is possible this included ten sets actually recovered from the MBSs. What is less certain is whether the display screen unit was operative. Only one image has been seen of the face of the display unit (on the first conversion, route 70) in May 1970). Perhaps they were used very briefly, but as explained earlier the use of these displays required very specialist wiring (a cost) and made use of the vehicles restrictive. Whatever the detail may be, the display screens were not part of any future AFC equipment and was quickly forgotten with standard

This is a May 1970 image of a Swift on Route 70 looking at AFC equipment from front, showing six fare push buttons and ticket slot. The fare display is mounted on a panel that looks very like the former Hounslow electronic display and as in the previous photo it appears this equipment was recovered and installed on the early Swifts on this route, but without electronic functionality.

This is one of the early Swift standee buses which appears to be SMS65 on display to the public in Harrow area before introduction of suburban flat fare service. This view looks towards front and appears to show equipment similar to that tested earlier on the Merlins in Hounslow, and which was probably the recovered equipment.

faretables displayed nearby, above the ticket selecting buttons (as on subsequent route conversions).

The early conversions to split-entrance AFC on graduated fares routes included children's fares, which were half the adult fare, three special fare buttons for children's fares being provided. This was quickly regarded as problematic. There was no check on whom might be buying a ticket or what fare was paid, let alone whether a ticket holder might be travelling beyond the validity of a ticket, and on-board random ticket inspection was not increased to compensate for loss of vigilance of a conductor, indeed some reports suggest there was less ticket inspection than hitherto (and driver's were not expected to detect or deal with ticket abuse). In such circumstances the ability for an adult to buy a child ticket to deliberately avoid paying the correct fare was an obvious loop hole and it seems to have been only a matter of months before children were required to buy tickets from the driver, the buttons going out of use. So far as can be determined the facility was never brought back.

The Future is Split Entrance AFC

Meanwhile the matter of double-deck vehicles had received attention. Routemaster production ceased in 1968, when it was obvious that the long term future had to be based on OPO. An attempt had been made to produce a front-entrance version but changes in government policy had resulted in new government grant money for transport operators being effectively dependent on LT buying off-the-peg commercial products, though they could be tailored (to an extent) to meet London needs. After much hand-wringing about the best approach, arrangements were made to purchase a variant of the Daimler Fleetline, known by some as 'Londoners', as they had been styled for LT service though based on a commercial product. These had already been tested in the country area and proved more satisfactory than the Atlanteans. Like the Swifts, these were to be supplied with a split entrance with one channel catered for by the new ticket-issuing AFC equipment and turnstiles (from 1973 a version with a conductor was also required and this did not have the AFC

This is the first Fleetline, DMS1, being displayed in September 1970 and shows the early form of AFC equipment that also appeared on the Swifts. The Fleetlines had 8-button ticket selection units from the start, though with no child fares and with equipment still able to accept only 3d, 6d and 1/- coins.

One of several leaflets produced in the hope it would encourage correct use of the AFC equipment.

equipment). Vehicles did not actually begin to arrive until the back end of 1970 but large numbers were ordered and it was expected 600 buses a year would be needed. 1,967 were already on order before any had been delivered and it is hardly surprising there were teething troubles (the same brave decision had been made with the single deckers and there were indeed teething problems). The first Fleetline entered service in January 1971.

Decimalization

While all this was going on the challenge of decimalization had to be faced. It was not planned that conversion to decimal coinage would itself be the trigger for a simultaneous fares change, and it is probably worth mentioning that in those days fares alterations were not the automatic annual event they became later, nor could they be unilaterally imposed by LT without approval of the GLC and the Prices & Incomes Board. We have seen that adult bus fares were generally based on sixpenny increments and it was on this basis that decimalization was to proceed.

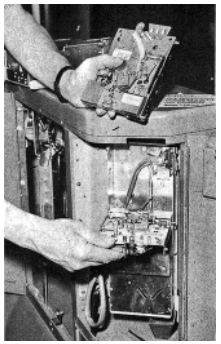
The challenge was that six pence in old money (for which there was a sixpenny coin) converted to 2½p (or 2½ new pence) in new money and there was not to be a new coin of that denomination. Shillings and florins (2-shilling pieces) had a direct equivalent in 5p and 10p coins which were the same size and were already circulating. Although it was recognized this would be a problem in the long term, the old sixpences were not to be demonetized for at least two years and LT felt that the very large number in circulation would allow the AFC equipment to remain in service without alteration for a while. Nor was it felt that retaining fares in 2½p increments would be an insuperable problem for drivers. However, on the basis that they would quickly be giving change in the new money, London Transport drew down 14 million half-pence pieces, pre-packaged, from the Royal Mint so that drivers would usually have change (perhaps a ½p for a 2½p ticket for which 3p were tendered). To further arm drivers with change, LT stockpiled sixpences for some months until they had 85 tons of them available (worth £750,000) and using its own equipment packaged them up into rolls of 40 (each worth £1) at the rate of 1000 rolls an hour. These allowed change for 2½p and 7½p to be given where 5p or 10p were tendered, and so on. This was all rather inconvenient but conversion had been planned over at least the previous year like a military operation and initially the arrangement proved satisfactory.

The next problem was that whilst the conversion day, or D-day, as it was termed, was set for 15th February 1971 it was quickly realized that London Transport was such a vast user of coin that special arrangements would be needed. It would be quite impossible to insist on correct payment in coin to the correct decimal value on that day because there would not be anything like enough new coin in circulation; indeed London Transport was regarded as an essential tool in getting new coins into use and withdrawing old coin. To the surprise of some, it was arranged that LT buses would 'go decimal' on 21st February when there would be plenty of new coins circulating. For logistical reasons the Underground would need to convert a day earlier, on 14th February, and this would help get the new coins into use.

A problem arose with bus child fares which involved increments of 3d, for which there was no exact decimal equivalent, and some rounding up and down was necessary to exact decimal on the relevant routes. This did not affect AFC equipment as children by then all paid the driver. There was an issue on the Red Arrows where the 9d fare then charged by the AFC equipment had no exact decimal equivalent and became 4p.

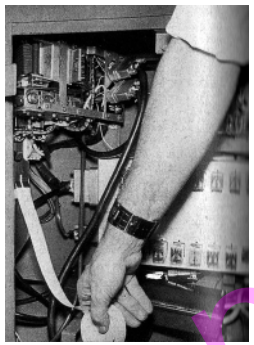
Although the sixpence had been a very useful coin, many shops and businesses quickly banked them after D-day and the public, whether through misunderstanding or otherwise, was wary about using them and despite the best efforts of the banks to keep them in circulation the public did not want them and they disappeared from people's pockets very quickly. They certainly disappeared from everyday use much faster than LT had hoped, quickly giving rise to an increase in change giving and less frequent use of the AFC equipment. Boarding times correspondingly increased and it was found that on split entrance buses 90 per cent of passengers were purchasing via the driver. This coincided with a low point in machine reliability anyway and did nothing

This shows one of the old coin acceptors in split entrance AFC equipment being replaced in July 1971 by a decimal unit taking 1, 2 and 5p coins.



to help to reduce boarding times. This could not be tolerated for long and in August bus fares on split entrance flat fare routes were altered to eliminate these ½p increments. The 2½p fare was rounded up to 3p but the 7½ and 12½p fares were rounded down. Kits were produced to aid the conversion and included circuit cards, replacement clip-in coin acceptors and new labels and notices. Each bus took about an hour to complete.

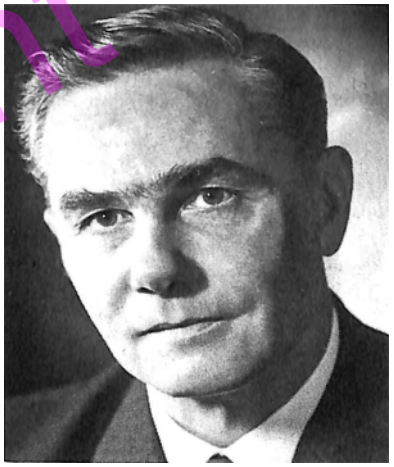
No changes were made to fares charged on other routes though the January 1972 increase on these routes rounded up the minimum fare to 3p. It was another year before all half penny increments were eliminated.



Equipment modifications included new, electronic coin acceptors and a new ticket issuing mechanism, these images showing new kit being installed and tested.

Technical Improvement

As mentioned earlier the AFC apparatus was designed by London Transport engineers to meet the urgent need for suitable equipment. The design used, in part, proprietary components reconfigured for use with a tripod gate. This approach was unavoidable, as at that time there was no AFC equipment to control entry to a vehicle in the way required. Some elements worked better than others, but some of the early components were really not suited to the job. For the Swifts and Fleetlines, London Transport specified the AFC equipment that was required and this was accommodated neatly into the overall design of the vehicle,



Sidney Haines, the engineer in charge of the AFC equipment.

LT arranging for the AFC equipment to be supplied to body manufacturers as needed. In service conditions it was quickly found that the equipment was very unhappy in the environment of a rattling bus and did not take kindly to what was being asked of it. In consequence, the equipment, which worked perfectly well in the factory, did not work so well when being bumped about in a moving vehicle. The consequential unreliability became a major problem and a huge disincentive for the public to use it.

By way of example, the original ticket issuing unit was provided by Bell Punch and used a concertina

The AFC equipment on a Swift taken on 19 February 1971. This equipment incorporates the eight fare buttons, there is no electronic fare display panel and a fare chart is now located at eye level above coin slot.

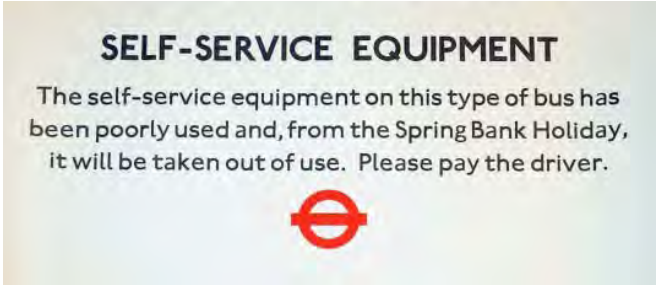
system of storing tickets which was found unsatisfactory in service and was prone to jamming (a problem made worse if bus was parked outside overnight and the pack got damp). This had a knock-on effect as it was necessary to pull the ticket out of the slot to release the turnstile and a jammed ticket would lock up the tripod barrier altogether. Because of the split entrance design, if a passenger got stuck because of a machine fault like this, the driver either had to release the turnstile and ask the passenger to deal with him direct, or get the passenger to return to the pavement and re-enter by the other half of the entrance. Either course caused a major delay and then the jammed machine still had to be addressed.

The all-mechanical coin acceptor, designed for vending machines, really did not like the hostile bus environment and was not very reliable. The tripods themselves were a problem as it was found that those unfamiliar with them sometimes tried to push them round by hand without actually passing through in the first turn. Since the mechanism only allowed a single movement, it then locked, leaving the passenger on the wrong side. This extra turn was sometimes made through trepidation but sometimes it was to ease through luggage; either way, this would cause a major delay even if it wasn't very frequent.

These problems emerged quite quickly and the first item to be dealt with was the ticket printing unit. Early in 1971 the Bell Punch unit on one of the Fleetlines was replaced by Setright equipment which was roll-fed and proved more satisfactory. In consequence, Setright equipment was quickly specified for new vehicles. During 1972 a substantial programme began of upgrading the existing AFC equipment. In addition to the new ticket issuing unit the turnstile was modified by incorporating a strategically placed photocell that stopped the tripod locking until a real person had passed through. Great effort was put into finding a better coin accepting unit and in the end a special more robust version had to be designed that made extensive use of photocells to check coins and a used a minimum of mechanical parts, much improving performance. Importantly it also accepted 10p coins, which at a time of mounting inflation was to be important. Other minor changes were also made and most of the improvement work was complete by the end of 1973.

A mid 1971 view of GLC officers inspecting a Fleetline bus. It may be seen here that on the later buses the turnstile bar now comprises just a stainless steel bar (the later Swifts also had this modification)

Although the refinements just described did improve performance, the process of buying the ticket from a machine was not particularly quick and it proved very difficult to get passengers not to buy tickets from the driver. In any event it did little to improve overall boarding times and although unreliability had been partly dealt with the equipment did not reach the levels of reliability hoped for. Although some equipment was removed there was little to be gained in taking it all out and drivers felt when it was busy the machines did take some of the load, and this was useful. Even so, by the end of 1979 both the Swifts and Fleetlines were already so unpopular with staff and passengers that withdrawal had already begun. AFC in this form was finally withdrawn as it was perfectly obvious that the technology was not up to the job and that either some radically different technology was required or other strategies had to be pursued to reduce boarding delays caused by the ticketing system.



This rather abrupt notice appeared in order to announce the end of AFC. It might be thought to suggest it was the passengers' fault!

Appendix 3
Part 2
'Plan B' – Off Bus Sales

Examples of the Ealing strip tickets, two different variants shown (one used from upper strip)

It is timely to remind readers that the objective was to reduce boarding times on one-person buses to (preferably) no more than two seconds so that bus operations remained attractive and economic. The idea that this could be done through on-bus sales by automatic machine was not working despite heroic efforts, so an alternative was needed. Logically, if one cannot realistically sell tickets on the bus, one needs to consider selling them off the bus. This was not the original aim but it became the focus when a 'Plan B', as we might call it, was needed. LT had little history of this. Although a number of Underground season tickets had for many years included bus availability, the facility had been allowed to wither and (as far as I can see) never overlapped with an OPO service, so there was no data. Inevitably numerous experiments were necessary in order to obtain the necessary data, and only from that could a fully-fledged plan emerge. In the event, off-bus ticket sales probably saved the day.

What was required was a mechanism by which tickets of some sort could be sold off the bus, and an on-bus mechanism to check validity, hopefully automated but necessarily manual at first. By such means, the delay in buying and paying for a ticket was reduced. If a sufficiently large number of off-bus sales were made then this might make an appreciable reduction in boarding times on OPO buses. Even after some years of applied effort, this was only a partial success.

Ealing

The first tentative experiment was made in Ealing, on the new flat fare routes E1, E2 and E3 and came into operation in October 1971. For this experiment, passengers could buy a strip of eight tickets from the driver for 30p, which entitled the passenger to make nine rides. No ticket was surrendered on the first ride but after that, one ticket was torn off and placed in the farebox each time a journey was made. The flat fare was normally 4p a trip so paying 30p rather than 36p represented more than a 16 per cent discount: the discount had to be attractive enough to sell sufficient tickets to see what impact it had on boarding times. By the end of the year LT was pleased with the take up of the new tickets but unfortunately early research suggested the system had not had much impact on boarding times and the implications of this were being considered. The following year's report notes that results continued to be disappointing and the plan was to increase off bus ticket sales further, to see if that would perceptibly reduce boarding times. To achieve this, strips of four tickets were made available from other outlets, such as newsagents from November 1972. The discount was 12½ per cent, or 14p a strip good for four 4p journeys. Although only a month's experience was covered by the report, these additional sales were also disappointing in terms of impact on boarding time despite 23 per cent of journeys being made using the strips. Since the shop sales had not had the desired impact, strip sales from these outlets ceased in September 1974, though on-bus sales carried on for a while. The experiment proved that it was possible to induce passengers to pre-pay, but had not succeeded in doing so in the numbers required to reduce boarding times.

Bus Season Tickets

On 11th June 1972 London Transport launched what was then considered a novel product—a ticket that allowed unlimited travel on all bus services at

any time. Sold as 'Red Bus Seasons' a monthly version was available at £6 and an annual version at £60. Using the monthly as a benchmark, if ten trips a week were made the cost per trip would be 13.8p which at that time would have only made sense for quite a long journey. However, for more frequent travellers, or those needing to change buses frequently, they had an attraction and were obviously convenient and overcame the challenge of having the correct change before every journey, which LT was increasingly demanding because change giving took time. From the same date a ticket called the Go-As-You-Please, previously available only to foreign visitors, was made available to anyone on demand. This gave unlimited travel on most of the Underground and all buses and again appeared in a monthly version for £13.50 and annual version at £130. These tickets were in effect the first Londonwide travelcards, though excluded the main line railways. The usual terror of revenue abstraction from existing tickets meant the price was rather more than ordinary season tickets, but they were convenient and suited those who travelled a lot but for whom a season was too restrictive. It was hoped that a useful proportion of people would take up one of these tickets thereby helping to reduce delays caused by paying on the bus. By the end of 1972 1000 annual red bus seasons and 500 Go-As-You-Please tickets had been sold and average monthly sales of each were 9000 and 500 respectively. This innovation showed promise but the challenge was now to make them readily available; at first, these tickets were available only at travel enquiry offices and fifty suburban Underground stations.

From 8th October 1972 a further experimental variant became available in the form of bus add-ons to Underground season tickets which served Finsbury Park, Turnpike Lane or Wood Green, the bus availability being confined to the associated flat fare routes. Tickets similar to ordinary Underground seasons were used on which was printed the bus route number or numbers from the relevant station. Where a ticket valid on one route shared sections of road with any of the other flat fare routes then the ticket could also be used on the other route along the common section. In all cases the additional season ticket charge made was £1.60 a month (or £4 quarterly). On boarding, the passenger had only to show the ticket to the driver. It is not apparent what impact, if any, this had on boarding times but it would have been helpful in rush hours at stops outside the stations. This experiment ceased from 2nd November 1975.

One of many leaflets that promoted the bus pass, perhaps the most useful initiative to help reduce boarding times before modern technology arrived.

In March 1974 the £6 monthly Red Bus Season became available at all Underground stations and National Travel agents and sales (which had by then reached 15,000 a month) rose to 20,000 a month. In June the product was renamed the Red Bus Pass. In March 1975 there was a very substantial fares increase but the price of the Red Bus Pass was unchanged, making it even more attractive. In addition it was arranged that a Red Bus Pass add-on (or 'extension') could be had for any Underground season ticket, making the product even more attractive (special season tickets were available marked 'Also Available as a Red Bus Pass'). The Red Bus pass went up proportionately more during the 1976 fares revision (to discourage transfer of passengers from the Underground) but still remained popular.

In June 1978 a Suburban Bus Pass was introduced covering the whole of London except the central area, and this was priced at £11.95 a month, compared with the all-London Red Bus Pass which by then had been increased to £14.75 a month. The new pass would appeal to those who might use buses to get to a station at the start or end of their daily commute by Underground, and a Suburban Bus Pass add-on was also made available to Underground season tickets. In 1979 the Red Bus Pass was renamed to London Bus Pass to distinguish it more clearly from its suburban cousin. Both were popular.

Yellow Door

From May 1974 a 3-month experiment took place on two routes using split entrance buses to increase usage of the automatic machines; one double and one single deck route was selected. This involved painting the right hand entrance yellow and use of prominent on-bus and leaflet advertising encouraging people to board via the yellow door and use the automatic machines. With further encouragement from inspectors located at strategic points it was found possible to double machine use. Some of this extra usage may have resulted from the new and more reliable equipment referred to earlier and which just needed passengers to discover for themselves that improvements had been made. Even so, the proportion of total passengers using the machines remained low and staff interviewed at the time did not believe that the machines were actually any faster than buying a ticket from the driver. I have been unable to find any move to carry on with the high profile yellow door publicity once the experiment finished.

One of the vehicles involved in the yellow door experiment. This was supported by advertising including the roof advert supposed to guide passengers towards the AFC equipment

Further Pre-Pay Experiments

In October 1973 fifteen flat fare areas began selling pre-paid tickets from the driver in the form of a 50p card of 12 tickets which, like Ealing, allowed an additional initial trip. Allowing 52p of travel for 50p was not particularly generous and induced only 5 per cent of passengers to switch, compared with a far larger percentage in Ealing. At the same time a no-change policy was introduced and this appears to have been behind the need for some other concession. However, for the substantial general fares increase in March 1975 the prices of these pre-pay tickets were not increased, so suddenly they became a great deal more attractive and offered a saving of 23 per cent, with consequential improved sales (a later fares revision further increased the savings these tickets represented).

On 14th September 1975 further pre-paid ticket experiments were introduced, this time on five suburban flat fare routes in the Wood Green and Muswell Hill areas (routes W1-W4). This time the purpose of the test was to try out multi-ride tickets which passengers had to cancel by machine on each trip. It was desired to test different types of equipment too. It was later hoped to extend the trial to graduated fares routes where automation had proved even more challenging. The trial essentially involved a 50p special ticket being issued authorizing thirteen rides for the price of five.

An example (front and rear) of one of the Wood Green experimental multi-ride cards, this one allowing 11 rides. The ticket has been wholly used so ride numbers (in left hand indent) have been entirely detached.

Tickets were purchased from the driver and validated before being handed to the passenger (validation information included coding and numbering and evidence of a sale requiring to be reconciled with the cash collected). After that (and on all subsequent journeys) the passenger inserted it into one of two cancellers, one near the driver and one on the nearside, on the cabinet where the AFC equipment had been. The ticket

was marked with a strip numbered 1 to 13 and on each use the block with the next number on it was removed. Magnetic stripes on the rear contained rudimentary coding that identified the card as a valid ticket and *LT News* recorded that if an invalid or spurious card were inserted the driver would be alerted by an alarm. In the first week some 4500 cards were issued, each available for use on any of the five routes. Passengers readily accepted them and the only adverse comment was that the cards were quite large and, if creased in pocket or bag, they might not work properly, or at all. By February 1976 a third of all journeys were being paid for by the multi-ride cards and they were about to be made half an inch shorter to mitigate crumpling problems (other measures were also being investigated).

There was some reflection about the discount and although the price was kept as 50p the number of rides authorized were altered on several occasions, partly required by the frequent general fare rises that rampant inflation was causing in those days. The 1976 annual report (published when the number of rides had dropped to nine) indicates that the Wood Green experiment had been successful and as a result further trial were to take place. This experiment rendered the 1972 season ticket add-on in the Wood Green area redundant (these were referred to earlier).

Poster promoting use of the Wood Green multi-ride ticket, showing an example of the ticket and the cancelling equipment, which was mounted on the top of the dead AFC equipment cabinet with turnstile removed. Another canceller is mounted behind the driver. Rides had reduced to nine at June 1976 fares change.

Multi-Ride Experiment Broadened

The next wave of trials was carried out with functionally similar equipment in other suburban flat fare areas. However the equipment itself was procured from several providers and one objective was to see how reliable the various types of equipment proved in practical conditions. Another was to test passenger reaction not only to the equipment but to varying rates of discount in order to calibrate a much larger experiment that was planned later.

On 17th July 1977 four express routes (C1, C2, C3 and C4) in Croydon were converted; a £2 multi-ride ticket permitted ten journeys at 20p and became an attractive proposition immediately as the cash fare was raised from 20p to 25p the same day.

A week later all the Morden 'M' routes and Peckham 'P' routes were converted on the basis of eight rides for 50p, saving 30p on the ordinary fares. Routes S1, S2 and S3 in the Stratford area were brought into the experiment from 2nd October 1977. This time a different technology was adopted where instead of sections of the card being cut off each time it was used an optical character reader was used to read the card. At the time this went live, Sidney Haines, the engineer in charge of developing bus AFC, observed that there had been 'teething troubles' but that 'the trials are going well'.

LT announced in April 1978 that the Wood Green, Croydon and Morden experiments had been successful and the equipment had proved satisfactory. In Peckham the equipment had not been satisfactory and it would be replaced. On the whole, this was thought positive news.

Havering

Following the success of the experiments on the Wood Green and other suburban flat fare routes, LT made the decision to proceed with a large scale experiment involving all the bus routes in Havering from 26th February 1978, the objective being to switch half or more passengers to the new system

(Havering was selected because bus routes and passenger movements in the area were mostly self-contained). It was recognised from earlier experiments that a very substantial discount would be required to achieve the required level of switch and most users enjoyed a discount of 50 per cent. The buses employed, generally operated a graduated fare system and for the purposes of the experiment the seven existing fares (ranging between 7p and 30p) were reduced to three fares at a higher-than-standard prices (10p, 20p and 30p) to discourage cash payments. As an alternative, the multi-ride card could be used, one unit (of ten purchased) being good for each 10p-worth of the fare. The units only cost 5p so this was exceedingly good value. On OPO buses, the passenger had to insert the ticket into the validator and indicate the required number of units to be deducted. On crew-operated buses the conductor had a device that did the same thing. The cards were valid on all buses within Havering as well as those starting or finishing journeys beyond. The scheme was heavily advertised including household distributions of leaflets and it was quickly found, with the heavy discount, to result in 75 per cent usage compared with cash fares that were still accepted by the drivers. Throughout 1978, LT was pleased with the take up but it resulted in a significant loss of revenue and, frustratingly, it still did little to reduce boarding times.

Universal Bus Ticketing System

The ticketing system tested in Havering was speculatively (and optimistically) called the Universal Bus Ticketing System and although much time was spent developing the idea, it was clearly not the answer. After much reflection LT thought that take up of the new tickets had eventually hit 80 per cent. Had it hit the 50 per cent target, the revenue loss created by the heavy discounting was expected to be between 2 and 3 per cent but the high take up was creating a 20 per cent loss and this was simply unsustainable. Calculations showed that in approximate terms it was possible to induce people to switch to bulk-buying travel in advance on the basis of a 1p discount creating a 1 per cent conversion. It may be seen that to discourage appreciable numbers of passengers from paying on entry to an OPO bus was inevitably going to be costly, almost to the point where it defeated the object of converting in the first place.

This was a very difficult time for LT and the entire future of vehicle purchasing hinged on whether UBTS would make OPO in London viable. LT believed that to keep a typical bus route functioning reliably boarding times had to be kept to no more than 1.9 seconds per passenger (it was 1.5 seconds on a rear platform Routemaster). Mid-year tests in Havering suggested that even with the high take-up of special tickets boarding times were running at 3 seconds per passenger. This was better than the 3.5 seconds noted on ordinary OPO buses but nowhere near what was required. With a great deal of effort and fine tuning LT thought they might be able to reduce suburban boarding times to 2.5 seconds but 1.9 was considered absolutely unachievable with the technology being tested and there were further doubts about whether the system was practical in central London conditions; there was 'little hope of achieving operational efficiencies with UBTS in its present form', the GLC was told.

Kerbside Conductors

In what seems like a desperate attempt to improve boarding LT agreed to a request by the passengers' committee to try a kerbside conductor at a busy stop in Woolwich from 10th October 1977. The stop served two very busy routes

and the idea was to sell the majority of tickets before boarding. Obviously it made some difference but this was hardly a practicable solution in most places and after the experiment finished we hear no more of it.

AFC On Hold

In 1979, LT finally conceded that all reasonable attempts had been made to reduce boarding times either by off-bus sales or by use of a wide range of automatic fare collection equipment and it was simply not possible with the available technology to reduce boarding times to the point where central London trunk bus services could be converted to OPO. The boarding time issue was of critical importance. Noted in the last section was the challenge of route operability because slow boarding promoted bunching of buses which was extremely difficult to mitigate with the crude supervision methods in use at that time. In addition it was one of the main factors that increased overall running time and this required more buses in service for any given frequency; this was expensive in needing to buy more buses and needed more drivers at a time getting drivers was difficult anyway. There was also some evidence of passenger resistance to the new methods, and vehicles, at a time when bus travel was falling anyway, which was another discouraging factor at a time when LT's standing instruction was to maximise passenger miles within available budget. However, in the long term, London was going to be stuck with buying vehicles essentially designed for OPO and the politicians were becoming increasingly preoccupied with London's high unit costs, particularly on the buses where comparisons (whether valid or not) could be made with other operators, so boarding times would some day *have* to be reduced somehow.

The immediate strategy would be to retain crew operation in central London with selective change to OPO to bring the proportion of OPO buses up from 45 to 50 per cent. Elsewhere effort would continue to reduce suburban boarding times. Meanwhile research would be undertaken for some kind of workable technological solution and the matter would be revisited in 1985. It was also hoped that penalty fares might be authorized which might allow passengers holding pre-paid tickets to board without a ticket check as penalty fares and spot checks would discourage those boarding without a ticket and with no intention of paying. Already noted in the section on Underground AFC, penalty fares did not arrive for many more years.

This was really the end of the road for any kind of automatic fare collection or inspection system on buses with prevailing technology and with so many relatively new and easily-maintainable Routemasters on the road. However, the pressure for efficiencies would continue and Routemasters would not last for ever, so LT had to consider other technological options, already noted in Chapter 17. In the meantime some structural changes to the fares system were made and these did have a positive impact on boarding times.

Flat Fares

It had long been recognized that flat fares were quicker to collect than the correct graduated fare. The issue for London Transport was that some bus routes were quite long and there was a well-ingrained belief that only a graduated farescale would appear fair to passengers, broadly represent cost of carriage and not discourage short journeys. There was terror that if a flat fare was introduced on a long route then short journeys would be discouraged and passengers on longer journeys would pay less than they were actually prepared to pay: the result would be an overall loss of revenue and over the system as a whole which was unaffordable in the prevailing financial conditions.

In a continued attempt to reduce suburban boarding times, and to gain knowledge about what would actually happen if flat fares were introduced, LT decided to install two experimental flat fare regimes. One would be in Harrow and the other in Havering, although the pre-paid tickets would remain available there as well. The experimental scheme was introduced as part of the fares rise on 24th February 1980 and a flat fare of 20p was charged for journeys in those areas. To London Transport's evident surprise this resulted in a 15 per cent rise in passenger mileage in those areas and no overall loss of revenue. In consequence it was proposed to introduce flat fares on buses throughout

London in the expectation that it would at least have some positive impact on boarding times.

What in fact was done was to introduce a flat fare system throughout the suburban area from 15th April 1981, with central London retaining graduated fares. The suburban boundary was approximately three miles from central London and about half of all buses operated wholly within the suburban area. Many of the rest operated partly in both and a minority in central London only. The suburban flat fare was set at 25p. We have seen earlier how the Underground fare zones emerged in October 1981, and these had to be overlaid on the bus fare zone just described. The suburban flat fare bus area eventually became Underground Zone 3, and the inner area was split into Zones 2 and Zone 1, from 1982 both also operating flat fares on buses within those zones. From this point, and the arrival of the travelcard, bus and Underground fares become inextricably mixed and the story is taken up in the chapter about smartcards.

No Cash

In a further attempt to reduce cash taken on central London buses, where boarding times were still considered excessive even though they, too, had become flat fare, the idea of using roadside ticket machines emerged. The idea was to cater for those who could not or would not use Travelcards and needed to pay by cash. Several experiments took place to understand human factors involved in machine location and layout and to understand maintenance and servicing requirements and this included a large-scale experiment on route W7.

The machines were located at bus stops and by paying cash a ticket was issued that was valid on any bus boarded within an hour. The bright red machines were mounted on a post as part of a year long experiment from summer 2000 and were located at: King's Cross, Waterloo, Finsbury Park, Camden Town Hall, Holborn station, Crouch End Broadway and Malden Road (Kentish Town).

After some tweaking it was considered the benefits were worthwhile and during 2003 kerbside ticket machines were installed throughout central London (more or less the area of the Circle Line) and also at stops serving the several articulated bus routes where these projected outside the main area. At this point the acceptance of cash on central London buses was withdrawn. Where route number plates were provided at stops they had yellow background on those routes where pre-payment was necessary. After the introduction of smartcards (and then contactless) the machines became so little used that most were removed from 2012 and drivers then took cash fares again on the rare occasions it was offered (though use of electronic payment was cheaper). The machines remained in use on W7 and Red Arrow services until electronic 'cashless' was available on those routes. With ongoing development of electronic payment the acceptance of cash on all London buses was withdrawn in July 2014 and the infrastructure required to handle cash was withdrawn from stops, buses and garages.

It took forty-five years, but at last cash was no longer responsible for excessive boarding times and ticket checking no longer caused delay beyond that resulting from the entrance design of the buses.

Example of one of the roadside ticket machines installed at central London bus stops. These were mounted on metal plinths and several styles of casing were employed.

Appendix 4
The Proposed British Rail Automatic Revenue Collection System

Background

In the main text, several references have been made to British Rail's intention to introduce AFC, which (as had LT in the early days) they termed Automatic Revenue Collection, or ARC. The proposals emerged from a programme that started in 1974 with assistance of EMI-Electronics from which it was decided there should be a trial at five typical stations in the London area. Progress was rather slow as to be meaningful the trial would have to accommodate various features required on the vast BR system and this needed a great deal of thought.

The need for ARC was actually very similar to that presented by the Underground: predominantly this was a substantial (but hard to quantify) amount of fare evasion and difficulty accounting for cash obtained from passengers travelling without having bought a ticket at the start. Problems were compounded by having a large variety of different ticket issuing systems in use, many of which were rapidly becoming life expired and would need updating, and some of which still required much tedious local book keeping and the use of value 'ticket' stock providing a target for theft. The desire was there for converting to a single system with automated accounting and perhaps automatic ticket examination (which was impossible with the old systems).

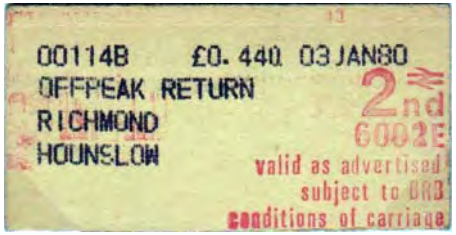
British Rail's problems were more complicated than those of the Underground, not least of which was the vastness of the network and the large number of ticket types and ticket routing possibilities. It was clear from the outset that in identifying a technical solution to meet only British Rail's business needs it would be mere chance if that solution would be the same as if LT came up with some-thing to meet only LT's needs. The inter-running of each other's services and large volume of through ticketing to and from stations well out of the London area made complete independence of approach impossible, and somehow whatever each organization came up with had necessarily to allow for seamless journeys from one system to the other.

A problem common to both LT and BR was range of technology apparently available and the lack of any existing system that was in any way comparable to either organization upon which it was possible to gauge useful experience. It is true that in Glasgow BR had installed a small ARC system in 1972, using magnetic tickets and comparable to the ill-fated LT scheme of the late 1960s, and not a platform upon which to build; experience gained (particularly about what not to do) was useful though. There was very little abroad either, and even the Americans had only small schemes on self-contained networks (and which were by no means fault-free).

The most urgent need to re-equip was in the busy London & South East area where there were about 800 stations that needed to be able to sell ARC tickets, of which 600 or so would be amenable to the installation of automatic gates. Tickets issues would have to be compatible both with LT destinations and Inter-City destinations outside the area.

Proposed ticket designs

The single-journey ticket size was to be based on the existing Edmondson card size (57mm x 30mm) and would have the usual printed information on the face and a magnetic stripe along the back containing similar information in coded form. Season tickets would be a larger format, as they already were, but modified in size to what became known as credit-card size, which the Inter City business had already decided it wanted to use (the larger format allowed more information to be printed as well as being easier to read).



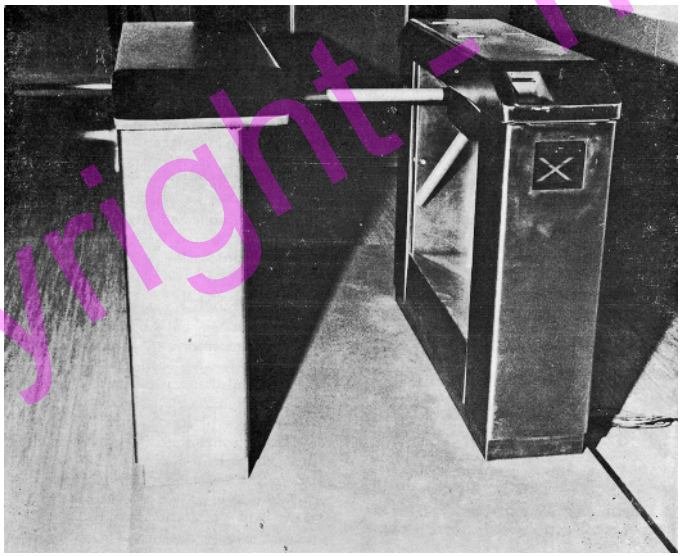
Example of one of the tickets devised for the BR ARC experiment. The design might be thought to lack finesse. The black was printed by a 9-needle matrix printer and the red was from a drum applying an appropriate printing block; this method was used to save space..

Most tickets would be of card but it was felt monthly and longer seasons would have to be made of plastic in order to be durable enough for repeated removal from wallets and insertion into the gates. All would be magnetically encoded on the reverse. This decision would require gates to have two ticket transporters and two ticket insertion points, one for each size (like the Underground's trial gate at Turnham Green). This was not ideal but seemed inevitable and was felt to be a problem that could be managed.

Tickets would release the gates, if valid, and if not valid would cause a red light to illuminate whence the passenger would find the 'call for aid' point where a member of staff could deal with the problem. There would be a facility for tickets to be captured at exit gates if the equipment were satisfied a passenger had definitely completed a journey.

Ticket Gate Design

There was some agonizing about gate design but ultimately the design hinged on the need for many gates to be reversible to handle peak flows and the huge space constraints that existing site conditions imposed. It was finally concluded that the familiar tripod gate design (using a set of three revolving bars unlocked for each passenger) was the most practicable design, notwithstanding some evidence of passenger dislike. The design had the benefit of being simple to use, operate and maintain and could be used for bidirectional flows.



One of the experimental British Rail ticket gates in late 1970s, location not known.

The design of the gate housing itself presented a formidable array of challenges, many of them very subtle and each capable of making the gate nearly unusable unless addressed properly. For example the ticket had to be inserted at the point passengers found easiest to use without slowing down appreciably. The ticket transport mechanisms had a definite minimum possible length, ordaining the nearest point the passenger could then retrieve the ticket. Ideally this would be near enough firstly to make it very difficult for anyone else to retrieve it, by accident or design, and secondly, if the ticket didn't work, to be able to step out of the way without having to try and reverse out against the flow, delaying everyone. The gate also had to expect passengers with briefcases and other impedimenta so the balustrading couldn't be unduly high. Then again, to provide some deterrence against bilking, the gates needed to deter improper use so far as reasonable. They needed to be professional to look at, easy to clean and simple to maintain. None of this was easy. Manual gates were to be provided for disabled people and anyone else unable to use the automatic gate, perhaps because of the amount of luggage or because they had a ticket that wasn't coded or didn't work.

Each barrier was to contain its own computing power, based on a Ferranti F100L micro-processor. The transport had to ensure the ticket was read at 30 inches a second and during its passage through the gate the code had to be read an rewritten very quickly. An added complication was the need to accept both the narrow and wide (credit card) ticket designs. In addition to the read and write heads a third set re-read the ticket to ensure the updated code had been correctly written. Two diverters were provided. The first, near the entry slot, returned a ticket that was apparently invalid. The second, much further back returned a valid ticket or diverted a finished ticket into a collecting bin.

Ticket Issuing Equipment

The tickets were all to be of non-value stock, generally partly printed and partly encoded at BR's own printing works at Crewe. This pre-printing might include reference to conditions of issue and possibly originating station. Each station would have an electronic ticket issuing machine into which the part printed ticket would be inserted. The clerk would insert the details of the journey and ticket type required and this would also be printed and encoded on the ticket, making it useable. The machine would keep full records of the transactions enabling rapid cash reconciliation both on the spot and centrally, and for the first time allow useful marketing data to be captured for later analysis. It was envisaged that after each ticket was printed, but before the ticket had left the equipment, the magnetic code would be validated to ensure it was properly encoded, reducing the opportunity for a defective ticket to cause a delay at a gate (let alone inconveniencing a passenger who might have paid a lot of money and would resent any suspicion of misuse being cast their way).

Experimental BR ticket issuing equipment suitable for ARC tickets. The box encloses the ticket issuing mechanism and electronics and the keyboard unit is the interface with the clerk.

The ticket issuing machine consisted of a substantial floor-mounted box containing the controlling electronics, ticket and tally rolls and a desk-top unit for the clerk at the window to use. The electronics was based around an 8085 computer and whilst the equipment had a substantial memory (for its day) it was still impossible to include the whole of BR's fare table and some little-required fares had to be looked up and entered manually. The most popular tickets could be issued by the press of a button but many tickets required the clerk to insert at least some additional information. This extra information could cover quite a range of information such as accompanied articles and animals and needed to include method of payment. The machines allowed for individual accountability of booking clerks and all transactions were recorded on a tally roll.

The ticket issuing equipment was considered quite successful and was eventually the subject of further development out of which the British Rail APTIS system (All Purpose Ticket Issuing System) was developed. The new APTIS machines began to be rolled out to BR ticket offices from August 1986.

System logic

The concept was designed to rewrite parts of the coding each time a ticket was inserted into a gate. The coding was designed to be written on the magnetic track in two sections. One of these was the fixed code that stayed with the ticket throughout its journeys. This comprised elements such as station from which issued, ticket type, date of issue and so on. The variable code section was expected to contain extra information such as the time and station at which the ticket was actually presented at the previous barrier. This was thought useful as an anti-fraud measure but one can conceive that it would be useful at various interchanges and perhaps important for tickets that were only valid at certain times. This part was also useful in making it impossible to use a ticket twice