London Transport Users Committee

Design of New Metro Stock: Briefing Report

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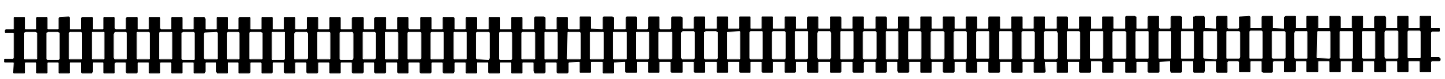

Executive Summary

The Railway Consultancy Ltd has been commissioned to write a short briefing note for London Transport Users Committee (LTUC) members regarding the design of new rolling stock for 'metro' routes on the National Rail network, to enable them to engage in consultation with the industry on an informed basis. This note is deliberately written in a more general fashion, in order that members may also consider the subject in the context of tube and other services which their remit covers.

The six key issues affecting railway rolling stock design from the passengers' point of view are discussed and shown to be:

- vehicle dimensions;
- seating and standing space;
- the number, width and spacing of doors;
- the reliability and speed of door operation;
- the size of vestibules;
- steps.

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1 Introduction

1.1 On a normal mixed-traffic railway, line capacity is determined by a range of issues, including:

- the number of tracks;
- the time taken by trains between adjacent signals; and
- the difference in speed between the fastest and the slowest trains.

1.2 On a metro or similar high-capacity urban railway system, however, there are usually only two tracks (one in each direction), and the performance of the trains is less of an issue because they tend to be all of a similar type. It is therefore the time taken by trains between adjacent signals which determines how many of them you can run and, therefore, how many passengers you can carry.

1.3 However, on an urban railway with frequent stops, the running speed is not the critical factor driving the time between adjacent signals, because trains rarely get up to their potential speed before having to slow down for the next station. Instead, it is the time spent in stations which is dominant. Quite simply, on urban metros, line capacity is determined largely by station stop times. There are a number of factors which determine these, including characteristics of the rolling stock, the station, the train service and the number of passengers.

2 Factors Affecting Station Stops

2.1 The ability to get large quantities of passengers off and on trains in a short period of time is itself dependent upon a number of detailed factors, including:

- rolling stock design (e.g. its sheer dimensions, the amount of door space available, the size of vestibules, double-deck stock);
- station design (e.g. the width of platforms, the number and placing of entrances and exits, and the stepping distance between the train and the platform);
- signalling system design (to minimise the time before a second train can enter the platform);
- safety features (the presence or absence of door close procedures, and platform-edge doors);
- train service design (do all trains serve the same stations?);
- train service regulation elsewhere on the line (e.g. are trains being dispatched at regular intervals from termini?);
- rolling stock and signalling system reliability (how common are failures?);
- staff performance and attitude (how quickly do they respond to routine events (such as the last passenger having boarded) and extraordinary events (such as a train failure, or passenger being taken ill)?);
- the numbers and type of passengers (e.g. commuters or tourists).

Most of these issues have been the subject of Operational Research studies, of which many were incorporated into LUL's Train Service Model (LUL, 1989).

2.2 On any given system, many of these issues are effectively fixed – but only in the short-term. Although this note concentrates on rolling stock issues, stations, signalling and staffing issues can also change over time, and members should consider the possibility of achieving the overall capacity desired by a range of means, and not solely through new rolling stock, important though that is.

2.3 This note also concentrates on issues of rolling stock design, although (as noted by Glover (2000)), reliability, availability and maintainability are also issues which should concern a train manufacturer. LTUC, as a passengers' group, should seek to ensure that, not only are trains designed with the passenger in mind, but that they are going to continue providing good levels of service for many years to come.

3 Metro Rolling Stock Design

3.1 There are six main features of rolling stock design which impinge upon its ability to minimise station stop times, which are:

- its physical length and width;
- the proportion of seats to standing space;
- the number, width and spacing of doors;
- the speed of door operation;
- the size of vestibules;
- the existence of steps.

These are considered in turn below.

Vehicle Dimensions

3.2 The loading gauge of a railway is a reflection of the clearance required by trains, in order that they avoid hitting surrounding objects such as bridges and platforms. The standard British loading gauge is more restricted than that on the Continent, and this limits the width of trains to around 2.7m (although trains limited to the Thames and Chiltern lines are wider, at 2.8m). Previous restrictions on train width (e.g. on the Hastings line) have generally been eliminated, for instance by singling the track through tunnels of limited width. However, the British loading gauge does make 3+2 seating a little cramped.

3.3 The actual dimensions of rolling stock are more variable than might be imagined. Especially in the older underground systems such as London's, trains may actually be relatively small (e.g. most LUL tube stock is around 50 cm narrower, and 3m shorter, than MTRC stock in Hong Kong or mainline rolling stock used in London – see also table below). Clearly, a variation of 20% in car capacity is critical when demand nears this capacity level. Moreover, this can be exacerbated by differences in train length (e.g. 7 cars is normal on LUL but 10 on MTRC).

Table 3.1. Selected Dimensions of Typical London Rail Rolling Stock
(all figures in metres, per car; some figures from Glover (2000))

	Length	*Width*	*Height*
LUL tube (1992, Central)	16.2	2.6	2.9
LUL 'C' (Circle line)	15.5	2.9	
LUL 'A' (Met line)	16.2	3.0	
LUL 'D' (District line)	18.2	2.9	
465 Networker	20.5	2.8	3.8

3.4 Even on the suburban rail network of Greater London, there is a potential variation in the length of carriages between Classes 455/6 used on SC and SW services (19.9m long), and the 23m-long vehicles of the Wessex Electrics used on longer-distance services out of Waterloo. Eurostar intermediate trailer vehicles are only 18.7m long. Train lengths on the suburban network vary between 2 and 10 cars, although proposals for platform lengthening to permit 12-car formations on the South Eastern network have been considered from time to time.

3.5 An ability to couple units together in the peak to make use of the maximum platform length is therefore key to the carrying capacity of the line (although passengers do need to be encouraged to spread themselves out along the train).

Seating and Standing Space

3.6 Secondly, the proportion of seats (as opposed to standing room) affects the ability of passengers to move both on/off and within the train (for instance, along a carriage to a less-congested area). London Underground's 'A' stock (on the Metropolitan line) has 56 seats per vehicle (which may be appropriate for its suburban role), but this makes it difficult for passengers to move along the train. However, the 'C' stock (used on the Circle line) has only 32 seats per vehicle, and KCR stock in Hong Kong has only 24 seats per vehicle. Not only does this maximise the number of passengers who can be carried in the peaks, but it also facilitates boarding and alighting.

3.7 The importance of this is that seating passengers take up more room than standing passengers. Not only is there the seat to fit in, but the area taken up by someone sitting down is larger than someone standing up. In the end, and for given rolling stock dimensions, if there are too many people sitting down, some passengers will be unable to board, which is clearly a worse problem. In addition, however, the longer times taken at stations also increase the journey times and reduce line capacity.

3.8 Market research is available which tells us how passengers feel about the relativity between sitting and standing, although this is also mixed up with how they feel about crowding. In completely crushed conditions, passengers can feel that their journeys are taking 2.5-4 times as long as they really are, although above a value of around 1.5, people tend not to board trains in the first place. A valuation of crowding can therefore give an indication as to the relative importance of seating and standing. However, passengers' expectations of having to stand tend to mean that they are less concerned about standing for short distances (e.g. Greenwich – London Bridge), and in those circumstances are more worried about not being able to board the train in the first place.

3.9 The PPP contracts at LUL specify very strict seating requirements to the InfraCos – much beyond what the market research would suggest.

3.10 The most recent 'metro' stock used by National Rail in the London area is the Networker fleet used by Connex on the south-eastern suburban lines. This rolling stock entered service in the period 1992-4, when finances were very limited. Government support from the Treasury was on the basis of vehicle cost per seat provided, which led to the construction of vehicles with as many seats as possible. Seating pitches are sub-standard, doorways too narrow, and standing space limited.

3.11 Traditionally, British trains have attempted to get 3+2 seating into our smaller loading gauge, although this leaves relatively little width per seat. Combined with pressures to squeeze in seats longitudinally (by reducing the pitch between seats to below 1.8m), suburban trains (in particular) are often cramped. With the average passenger getting larger, this is an increasing problem; seats are commonly too narrow (at around 460mm) as well as providing insufficient leg-room (which is often more of a problem with facing seats). A suitably-large LTUC member should be used to find what is an acceptable seat size, but this debate does imply that 2+2 seating should carefully be considered. On how many journeys per day are the maximum number of seats actually used? And how comfortable is it when they are all used?

3.12 The refurbished 319s for Thameslink have taken this into account, with 2+2 seating replacing 3+2 seats. This actually permits a higher peak carrying capacity (albeit with standing) whilst improving comfort levels offpeak. With the higher luggage requirements of Thameslink (serving, as it does, both Luton and Gatwick airports), this was clearly a sensible alteration for that service.

Number, Width and Spacing of Doors

3.13 Thirdly, the number, width and spacing of doors impacts directly on the number of simultaneous boarding and alighting movements that can be made. Very roughly, one person can pass through a door 1m wide every second. Although it may not seem very much, any feature which reduces this flow rate to (say) 0.9 persons per second will detract significantly from line capacity. If there are 100 passenger movements through that door in a journey in the peak (50 people on + 50 people off), the slower rate will add 10secs to the journey time. On a busy metro line, this is critical because times allowed for accelerating and decelerating, and for signals to change, are effectively fixed; all the slack time in the timetable (and perhaps more) can disappear in slow boarding and alighting times.

3.14 The first batch of rolling stock for LUL's Jubilee line contained single-leaf doors throughout, which proved inadequate in providing for passenger movements. Most other LUL stock still has single-leaf doors at the ends of the carriages, limiting movements to one per door at once.

3.15 Many rolling stock types have 'double' doors 1.3m in width, but observation shows that rarely are these wide enough for simultaneous movements. Wider doors (such as those on 1992 Central line stock (1.7m wide)) are required; narrower doors (such as the 1.1m-wide doors on Networkers) are clearly insufficient, and are easily blocked.

3.16 Most suburban rolling stock has two doors per car, at the one-third:two-thirds positions along each carriage. This is demonstrably better (in station stop terms) than InterCity rolling stock with doors only at the ends of the cars, but demonstrably worse than LUL stock with a greater number of doors. In a 20-m vehicle, seating capacity per vehicle with two doors can be as high as 84, but is probably only 64 with three doors (and typically only 40 in tube stock with four doors). A balance needs to be struck – but for inner-suburban operation, three doors are more important than more seats.

The Reliability and Speed of Door Operation

3.17 In addition to the number, width and spacing of doors, the equipment used to open and close doors itself needs to be considered. Train doors get a great deal of use. Even when a door is fitted with selective door controls (so that it is not opened at a station if no-one wishes to alight or board), it is likely to be operated hundreds of times per day. Doors are mechanical devices subject to the usual wear and tear, supplemented by additional stresses such as being forced open by passengers anxious not to miss their train. It is therefore no surprise that door failures are amongst the key operational problems of metro and suburban railways. With door failure leading immediately to vehicles being taken out of service, the manufacturer of any new train must pay particular attention to the reliability of the door opening/closing system.

3.18 As greater attention has been paid both to safety and reliability, door-opening mechanisms have become more complicated. To save money, manufacturers and operators have sometimes responded by reducing the number of doors but, as we have already seen, this has disbenefits in terms of boarding and alighting rates. Other new systems are relatively slow (time door openings on the JLE (at around 4 seconds) with those on other tube and metro systems). Without wishing to continue the practice of slam-door stock (on which passengers can open the doors outwards *before* the train comes to a stop), reducing door-opening/closing times to a minimum is important – it could be worth two seconds per station stop every single time a train stops at a station, for the next 30 years.

3.19 Moreover, on lines with variable train lengths, it is not always possible for trains to stop at the same place along the platform (as happens on the Jubilee line, adjacent to

the platform doors). Time can be wasted whilst passengers walk to the nearest door. The fewer doors there are, and the less distinctly they are coloured, the longer the time wasted. With vehicles with only two doors per car, it is quite possible to be 6m from a door when the train stops. Three doors per carriage therefore reduce the access time to the train, and strongly contrasting door colours are therefore a benefit to the operator and all passengers, not just the partially-sighted.

Vestibules

3.20 Fifthly, the size of vestibules affects the number of people who can be ready to alight when a train arrives at a station. Within this, the width of the 'standback' (that area behind the doorways) is also significant in determining whether passengers not alighting at a station interfere with boarding and alighting movements.

3.21 The positioning of grab poles within the vestibule area is an area of contention. They can help the mobility-impaired if such poles can be reached during the step into the train, and it certainly helps passengers' balance during the ride. However, they can also get in the way (for instance, if centrally-located in a relatively-narrow doorway). If located too near the doors, they can also discourage passengers from moving further into the train (hence freeing up more space for others to board).

Steps

3.22 Finally, the existence of steps (either within vehicles, to access an upper floor) or between the vehicle and the platform (to reduce the stepping distance) also reduces passenger flow (for the able-bodied, as well as the mobility-impaired). Increased stepping distances can be a direct consequence of longer vehicles if platforms are not entirely straight, since more room has to be left for the train to sweep round the corners. In other situations, rolling stock design deliberately impacts on passenger flow; double-deck stock on RER line D (Paris) has been recorded as having passenger movement rates significantly lower than normal, at below 0.7 passengers per second per door.

3.23 Some mainline railway stock has steps to enter the vestibules, in order to cope with a difference in height between the platform and the train interior. In the longer-term, this should become less of an issue, since Railtrack has a programme in hand to standardise all platform heights. However, problems will remain in the short-term. The 'double-step' arrangement of Networkers appears to be particularly unfortunate, in that the steps are relatively small. Observations shows that smaller people take time in carefully placing their foot on the lower step, whereas larger people take time before striding across both steps. Where this stock is deployed on intensively-used lines (as, for instance, on the Bexleyheath line), this can be an important feature in determining line capacity.

3.24 In summary, therefore, steps should be avoided on efficiency grounds (as well, of course, as on grounds for the mobility-impaired).

4 Conclusions

4.1 Attention to the detail of rolling stock design pays dividends in the successful efficient and passenger-friendly operation of those trains over their lifetime. Key issues to be considered are:

- vehicle dimensions;
- seating and standing space;
- the number, width and spacing of doors;
- the reliability and speed of door operation;
- the size of vestibules;
- steps.

References

Glover, J (2000) "Principles of London Underground Operations", Ian Allan, 160pp.

Acknowledgements

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