A European Comparison of Station Stop Delays

Nigel G Harris
The Railway Consultancy Ltd,
1st floor South Tower, Crystal Palace station
London SE19, UK
nigel.harris@railwayconsultancy.com

Abstract— Train service operation and modelling requires a good understanding of the delays which may disrupt performance at stations. However, few of these smaller delays are measured properly, let alone understood. This paper reports ongoing research on European railways into the magnitude and distribution of minor delays at stations, the reasons for their propagation, and possible management strategies to mitigate them. Results will be important not only for train service modelling, but also for their direct application to immediate service improvement.

Keywords— Railway operations; Operational planning; Station stops; passenger behaviour

I. Introduction

Urban rail capacity is determined as much by the management of station stops, as it is by other elements of the rail system (vehicles, track layout and signalling systems) [1] (Vuchic, 2005 pp. 80ff.). Yet although many researchers have developed simulations for railway operations, most of these treat station stops as fixed, thereby ignoring a key element of rail system variability. However, not all of that station stop time variability is random and even some that is can be understood and hence managed.

An ongoing international work programme of analysis of the rates at which passengers alight from, and board, trains [2] led to the examination of the impact of rolling stock features and other factors determining passenger movement rates [3][4]. This has led on to the consideration of the other types of delay from which train operators suffer at stations, and a case study of impacts in the Oslo area of Norway [5]. That paper highlighted and quantified six major types of delay in the station stop process, viz.:

- train stopping imprecision;
- positioning of the train conductor relative to the busiest (critical) door;
- delays in the despatch process;
- passengers forcing doors (or preventing them from closing);
- excessive customer service (traincrew waiting for passengers who are already late);
- knock-on (signal) delays caused by preceding or opposing trains.

Note that variations in the sheer number of passengers alighting and boarding are not seen as a delay per se, since passenger movement is the rationale behind stopping at stations in the first place; nevertheless, train operators can affect this by judicious train planning (taking into account desired travel times, train service frequencies, destinations and stopping patterns).

Although huge numbers of railway simulations have been built over the years (see COMPRAIL conference proceedings for many examples), and other authors (e.g. [6]) have postulated the underlying (un-delayed) relationships, our paper on the Norwegian experience was the first to set out the underlying data distributions. The follow-up question to that paper is therefore whether the Norwegian data is typical of conditions elsewhere. This paper uses examples from two other European cities to undertake a comparative analysis, in order to answer that overall question. In fact, there are three subsidiary questions:

(i) do the same factors apply?
(ii) if so, do they apply at similar rates/ in similar proportions to each other?
(iii) are there other factors which need to be taken into account?

II. Background

The other cities for which data at the required level of detail has become available during 2014 are Munich (Germany) and London (UK). The specific railway operating situations also vary, enabling us to gain insights on the impact of differences in train service. However, in all cases, analysis has concentrated on peak period operations at relatively busy stations (this is partly to enable the efficient collection of sufficient data).

Suburban rail services in Munich are provided by the S-Bahn, currently operated by DB Regio, a subsidiary of national rail operator Deutsche Bahn. A particular feature of this system is the linkage of multiple branch lines through a core section between Pasing and Ostbahnhof (see Figure 1); this leads to very high train service frequencies of up to 30 tph (trains per hour) passing through the key stations at Hauptbahnhof and Marienplatz. Although all services were formed of Class 423 units when surveyed, these were provided in both 8- and 12-car formations.

London has a dense network of suburban rail services, but many lines run at 15-minute frequencies merging into inner-area corridors with higher frequencies, and a dataset from that is also available. This has been limited to peak observations of 8-car trains all of the same type, on a line in which 4-car sets, or 8-cars of other rolling stock types can occasionally be found. In aggregate, then we are able to consider differences both in national context (which might be expected to be reasonably low, since all three countries are in N W Europe) and also train service frequency (which, *a priori*, would be expected to affect the number of knock-on delays).

III. Results

Because delays do not occur to every train, and because some of them are very short and are often thus missed during analysis, only stations where relatively large datasets are available have been included in this analysis. Table 1 summarises the datasets used. The shorter and more focussed station stops required by “pipeline-type” operation in the core section of the Munich system is clearly marked, in comparison to other sites where some trains wait for time.

In order to provide a comparative analysis, we now turn to the range of delay types identified in our previous work for NSB, and examine them one by one.

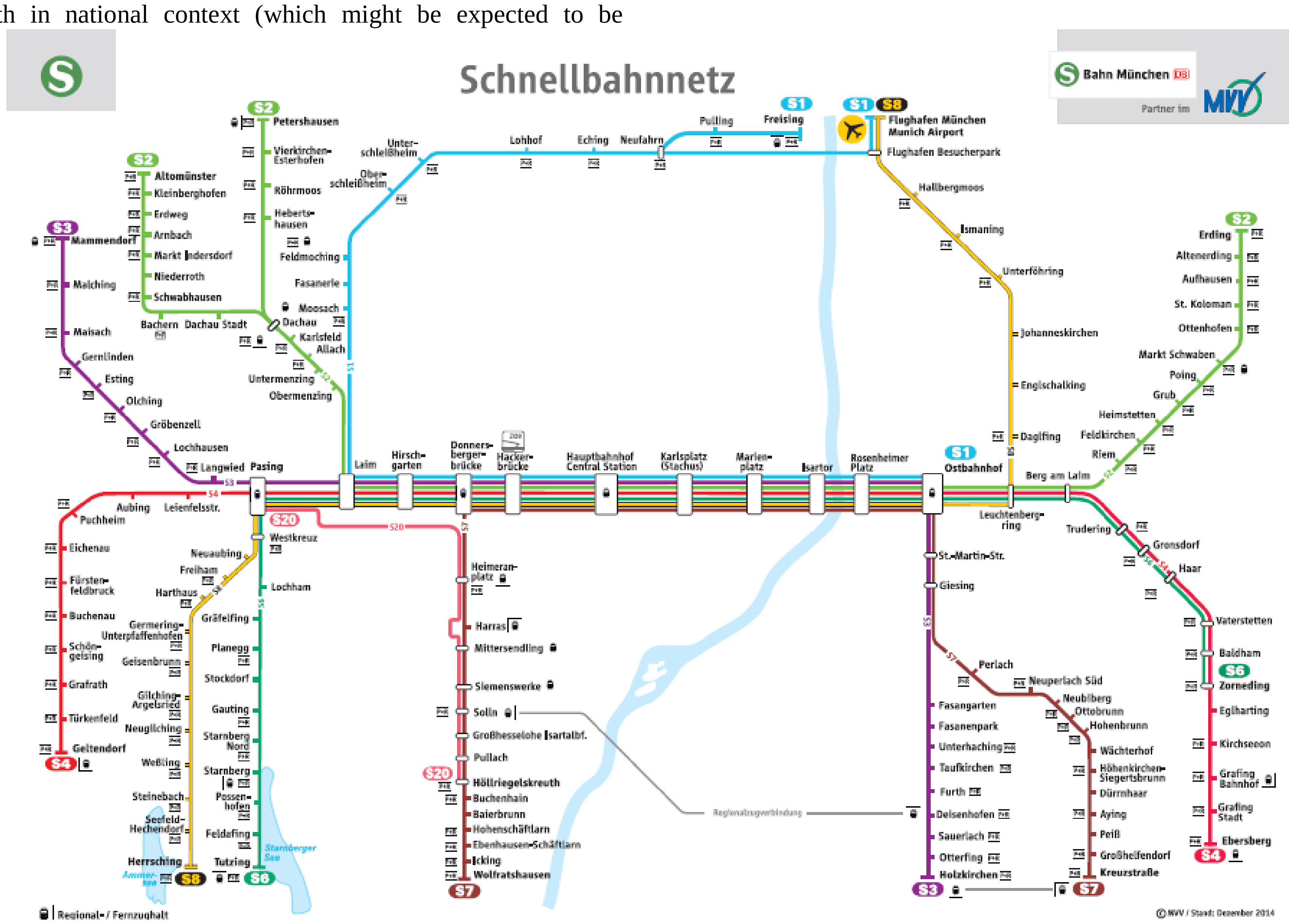

Figure 1. Munich S-Bahn Suburban Rail Network

TABLE 1: SUMMARY OF STATION STOP TIMES

City	Station	Direction	Number of observations	Across all observations	
				Mean (secs)	Std. dev. (secs)
Os	Nationaltheatret	Eastbound	90	73	54
Os	Nationaltheatret	Westbound	100	58	24
Os	Sentral	Eastbound	84	130	43
Mu	Hauptbahnhof	Eastbound	48	39	6
Mu	Isartor	Eastbound	51	27	6
Mu	Marienplatz	Westbound	34	35	5
Mu	Ostbahnhof	Westbound	109	180	115
Ln		Northbound	50	58	30
Ln		Southbound	49	59	29

A. *Train Stopping Imprecision*

The range of train types and lengths suffered by NSB is not replicated in the other operators so one would not expect this to be so much of an issue elsewhere; moreover, the end-loading of key platforms in the Oslo area makes train positioning more critical. However, the dataset reported in [5] and also used here precedes the installation of new stopping boards specifically designed to reduce the impact of this problem. Early evidence suggests that this equipment has had positive impacts, even if the level of success seems to vary considerably between stations.

TABLE 2: STOPPING PRECISION DELAYS

	Station	Mean where occurred (secs)	Across all observations	
			Mean (secs)	Std. dev. (secs)
Os	Nationaltheatret Eb	18	17	10
Os	Nationaltheatret Wb	15	12	11
Os	Sentral Eb	18	17	10
Mu	Hauptbahnhof Eb	0	0	0
Mu	Isartor Eb	0	0	0
Mu	Marienplatz Wb	2	0.1	0.3
Mu	Ostbahnhof Wb	0	0	0
Ln	Nb	0	0	0
Ln	Sb	0	0	0

Having a standardised train fleet clearly makes it easier to organise the stopping of trains at consistent place along a platform, especially if the train is of the maximum length to fit in the platform. However, even including the two trains in the London Southbound dataset which were not formed of 8 cars, there were no delays at all from this cause.

B. *Staff Positioning*

In the case of NSB, services were all operated by trains with two members of staff, a driver and a conductor; a key responsibility of the latter was to ensure speedy alighting and boarding, although this requirement can be compromised by other duties the role entails (e.g. revenue protection or customer information). However, the other data described here are from services operated as driver-only, without platform attendants, so they do have staff directly available to manage

TABLE 3: STAFF POSITIONING DELAYS

	Station	Mean where occurred (secs)	Across all observations	
			Mean (secs)	Std. dev. (secs)
Os	Nationaltheatret Eb	2	1	1.7
Os	Nationaltheatret Wb	4	2	3.5
Os	Sentral Eb	8	2	4.8

passenger flows (Munich uses staff in a control point mounted high above the platform to assist with despatch). The values for the other operators are therefore, by definition, zero, although one would expect this to be countered by longer despatch delays (see below).

This leads to an important conclusion: delays can be minimised by simplifying procedures, for instance by having fewer staff involved in the process (delays caused by poor liaison between conductor and driver cannot occur if the train is driver-only operated). Various reasons are public adduced for switching to driver-only operation, but a reduction in delays is rarely one of them, even though it appears to save 1-2s per station stop.

C. *Despatch*

Several different types of delay may occur during the despatch process, especially if this is a multi-stage affair. The first type of delay is for staff to wait unduly long after signal clearance and the movement of the last “clustered” passenger (to use Daamen’s term [7]); “late runners” from that moment should not be waited for, as the net (larger) benefit to them is much smaller than the aggregate disbenefit to all those already on the train, and those on other trains which will interact with the observed train. We have defined “unduly long” to be 10s: this should be more than ample time for a driver to be sure that passenger movement has finished, and for them to initiate door closure.

However, the second type of delay is the response by the driver to any “ready to start” sign provided by platform or control staff; this delay manifests itself in an undue length of time between that signal being received, and wheel start occurring. Nevertheless, because different types of rolling stock have different physical features and operating requirements (e.g. door interlocking times), such delays have been excluded from this analysis. However, observations demonstrate that new technology does not always help in minimising times: for instance, more modern trains often have more sophisticated door closing equipment which actually takes longer to operate.

The notable difference between the datasets was the number of occurrences in London where despatch started unduly early i.e. before 15 seconds before the booked departure time. These led to early departures, up to a maximum of 34 seconds, which is not good practice.

TABLE 4: DESPATCH DELAYS

	Station	Mean where occurred (secs)	Across all observations	
			Mean (secs)	*Std. dev. (secs)*
Os	Nationaltheatret Eb	10	-1	11.6
Os	Nationaltheatret Wb	11	3	12.4
Os	Sentral Eb	17	9	15.5
Mu	Hauptbahnhof Eb	4	-2	4.7
Mu	Isartor Eb	2	0.04	0.3
Mu	Marienplatz Wb	2	-4	3.6
Mu	Ostbahnhof Wb	11	2	6.2
Ln	Nb	9	-3	5.3
Ln	Sb	15	-0.1	7.8

D. Door Forcing

Passengers keen to board can cause delays by trying to do so:

- after clustered boarding has been completed (if the train is already due to depart);
- after the door close process has already started (possibly requiring it to be restarted); or even
- after the door(s) have actually closed.

The exact nature of train door systems can impact on this: for instance, NSB's older Type 69 trains (of which there are many in the sample reported here) can have their doors re-opened by passengers, even after the conductor has authorised their closure. However, this is not possible with most newer trains, including NSB's Types 74 and 75. Other design features of trains intended to minimise the possibility of doors being re-opened or forced have been discussed by [8].

The above results are reasonably similar, but one might expect different passenger behaviour in places with different cultures (e.g. Latin America, or the Far East). Detailed instructions to traincrew as to how to manage this (e.g. by partly, not fully, opening the doors before attempting to reclose them) can help punctuality at the margin.

We were surprised to discover that the prevalence of door forcing delays was not higher in London than in either Munich or Oslo; only two instances were observed. In only one occasion was the delay noticeable, as doors were held whilst a passenger sought information on the destination of the train, when the platform describers were out of order. On the other occasion, the delay was only at the margin of door operation, so that a full re-opening of the doors (with the consequential

TABLE 5: DOOR FORCING DELAYS

		Mean where occurred (secs)	Across all observations	
			Mean (secs)	*Std. dev. (secs)*
Os	Nationaltheatret Eb	6	0.2	5.7
Os	Nationaltheatret Wb	10	0.1	1.0
Os	Sentral Eb	13	0.6	3.0
Mu	Hauptbahnhof Eb	7	0.9	2.6
Mu	Isartor Eb	0	0	0
Mu	Marienplatz Wb	8	0.7	2.3
Mu	Ostbahnhof Wb	7	1.4	4.5
Ln	Nb	0	0	0
Ln	Sb	1	0.7	4.4

time penalty) was not necessary, but rather that the remainder of the passenger's body and/or luggage needed to be scraped through between the doors.

E. Knock-On Delays

One would expect a key determinant of these to be the relative complexity of the infrastructure at each location, so we also indicate in our summary of results below the type of station layout. Some are simple ("linear") stations with only one track in and out, whilst others ("Multiple") have several tracks in and out, others fall at a junction ("Converging" or "Diverging") whilst yet others are "Complex". Although the location in London was typically only operating at a maximum of 8tph per track in the peak, it is noteworthy that not a single train was prevented from leaving the platform by a red signal (although some left under cautionary aspects).

TABLE 6: KNOCK-ON DELAYS RESULTING FROM SIGNAL CHECKS

	Station	Location type	Mean where occurred (secs)	Across all observations	
				Mean (secs)	*Std. dev. (secs)*
Os	Nationaltheatret Eb	Multiple	10	4	26.8
Os	Nationaltheatret Wb	Multiple	70	4	19.9
Os	Sentral Eb	Diverging	0	0	0
Mu	Hauptbahnhof Eb	Linear	0	0	0
Mu	Isartor Eb	Linear	0	0	0
Mu	Marienplatz Wb	Linear	0	0	0
Mu	Ostbahnhof Wb	Converging	62	17	38.3
Ln	Nb	Converging	0	0	0
Ln	Sb	Linear	0	0	0

In a "Linear" context, knock-on delays would be expected to be relatively small and few, since the occupation times of track circuits including platforms would be expected to be higher than those between stations. However, train Service Regulation can be a problem at "Converging", "Multiple" and "Complex" locations. Here, staff (either in the control centre or on the platform) are required to undertake an instant assessment of which trains should depart in which order. For a timetabled suburban operation, the first choice for this would typically be in their booked order, but sufficient lateness of one service relative to another can make a change in train order appropriate.

F. Other Factors

Physical Environment: This paper is not the place for a comprehensive treatment of (e.g. train design, platform design, passenger flow) issues surrounding passenger movement time (see, for instance, Harris et al, 2014). However, it is reasonable to note that large train:platform gaps (of up to 40cms, if both vertical and horizontal gaps are taken into account) on some of London's busy urban railways do reduce passenger movement rates.

Crowding: Moreover, significantly-reduced passenger flows (as low as 0.1 pass/sec) were observed in the London surveys analysed here, because of crush levels of overcrowding (on trains with vestibules sized at 3.1m^2, 19 occupants implies a passenger density of c.6 pass/m^2 of standees). This happened on a few height-of-the-peak services on all days surveyed, but a rather larger number of trains on November 5th, since a major fireworks event was taking place a few stations along the line. The provision of insufficient capacity (albeit understandable during "events") is a further factor delaying trains at stations. Boarding rates were observed to fall to as low as 0.1 pass/sec; even 0.5 pass/sec would, for 10 boarders per door, lead to a delay of up to 10 seconds compared to what might be expected.

Manual door operation: One choice for the operators of urban railways is whether train doors should all open automatically upon release by the driver at each station, or whether they should be individually-operated by passengers. Expecting more passenger movements, and less slack time, metro operators normally opt for the former of these, but suburban railways can choose either. A potential delay here can occur if passengers expect the doors to open automatically, and so do not activate the buttons until after they have realised that automatic operation will not take place. This is difficult fully to observe (one needs to be both outside and inside the train at the same time), but one specific delay of 6s was observed in London. As expected, this was during an offpeak period, when more unfamiliar passengers might be expected.

Awaiting departure time: Suburban railways have an operational disadvantage that passengers are informed of specific departure times, so it is sometimes necessary to await this, even if the train is ready somewhat beforehand. This was a frequent occurrence in London, although this is not necessarily a "bad thing": train services need to be regulated somewhere, and those arriving without delay will, by definition, not need the time to recover from such delays. However, trains were observed departing early, by up to 34s, which is unacceptable given the publicly-quoted policy.

IV. Conclusions

Use of a standardised observational and analytical method has enabled some conclusions to be drawn about the relative frequency and magnitude of types of station stop delay on European railways. On the one hand, the results can be dismissed as being unduly dependent upon the specific physical and train service characteristics of the stations surveyed. However, the use of multiple datasets from critical locations does realistically give us some guidance about the types of problem that national operators face – and, in some cases, manage. The summary results shown in Table 7 below are therefore designed to inform planners as to realistic patterns of delay, and to provide managers with encouragement towards best practice from benchmarking their operations against others.

The management of such pipeline-like railway operations in urban areas is clearly challenging. A key element of this is that station stops have to be managed tightly, in order for the flow of trains to continue unimpeded. If patronage increases (as it is forecast to do in all three of the cities analysed above), detailed operational management will become even more

TABLE 7: SUMMARY OF DELAYS

	Typical delay per train (seconds)		
	Oslo, Norway	*Munich, Germany*	*London, England*
Train Stopping Precision	12-17	0-0.1	0
Conductor Positioning	1-2	0	0
Despatch	-1-9	-4 – 0	-3 - 0
Door Re-Opening/Forcing	0-1	0-1	0-1
Knock-On Delays (Signal Checks)	0-4	0-17	0
Knock-On Delays (Regulation)	0	0-8	0
Platform:Train Stepping Distance	0-1	0	0-5
Crowding	0	0	0-10
Total	*12-34*	*-4-26*	*-3-16*

interactions of passengers and trains.

We would expect the size and complexity of a railway to affect the culture of both passengers and staff. Oslo is clearly quieter than Munich which, in turn, is quieter than London, and this may help to explain the slower processes generally recorded in Norway. However, although the results from London indicate good operational performance on many measures, the older and more crowded nature of the British railway network is clearly working against top-quality accuracy in operations. Allowing trains to depart early, in order to counter some of these problems, is not recommended; instead, we would hope that the type of analysis undertaken here would enable operators to plan their services to much greater levels of accuracy in the first place.

Acknowledgments

Thanks are given to those train operators who gave permission for us to undertake surveys on their stations, and to colleagues Michael Gödde (DB), Christian Mjøsund (NSB) and Hans Haugland (RCL) for specific comments.

References

[1] Vuchic, V R "Urban Transit Operations, Planning and Economics", New York: Wiley, 2005, 644pp.

[2] Harris, N G & Anderson, R J "An International Comparison of Urban Rail Boarding and Alighting Rates", Jnl. Rail & Rapid Transit 221 F4 2007, pp. 521-526.

[3] Harris, N G "Train Boarding and Alighting Rates at High Passenger Loads", Jnl. Adv. Transpn. 40 (3) 2006 pp. 249-263.

[4] Harris, N G, Graham, D J, Anderson, R J & Haojie, L "The Impact of Urban Rail Boarding and Alighting Factors", TRB 3rd Annual Meeting, Washington DC, USA, 2014.

[5] Harris, N G, Mjosund, C S & Haugland, H "Improving Railway Performance in Norway", Jnl. of Rail Trans. Plan. & Man. 3 2014 pp. 172-180.

[6] Weidmann, U "Der Fahrgastwechsel im öffentlichen Personenverkehr", Schriftenreihe des IVT, Zurich, 1994, no. 99. (in German)

[7] Daamen, W & Hooghendoorn, S P "Pedestrian Traffic Flow Operations on a Platform", Proc. COMPRAIL 2004 pp. 125-134, WITpress, Southampton, UK.

[8] Coxon, S, Burns, K & de Bono, A "Design Strategies for Mitigating Passenger Door Holding Behaviour on Suburban Trains in Paris", 33rd Australasian Transport Research Forum Conference, Canberra, 29 Sep – 1 Oct 2010.