Trafikministeriet

Summary / Kolofon

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The Railway Consultancy Ltd.
43A Palace Square, Crystal Palace, London. SE19 2LT.
Tel +44-20-8653-1097
Fax +44-20-8771-3171

Ministry of Transport, Denmark

Station Capacity at Norreport

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1 Introduction

1.1 A metro system in Copenhagen has been planned for some time now, the Western route of which is due to link the city centre with the suburb of Vanlose. This will complement the S-Tog network, with which it will have an interchange at Norreport station. Here, the metro (running underground, on a North West to South East axis) will cross the S-Tog (and other mainline rail) lines (running broadly South West – North East).

1.2 Much future traffic is expected to make the interchange between the lines at Norreport, and considerable effort has gone in to analysing the requirements for passenger flow in the longer-term. However, a short-term problem has been uncovered. During the period of works for the metro station at Norreport, parts of the S-Tog platforms will have to be closed off, for construction works. With this already being a busy station, there is a possibility that the remaining areas will be insufficient for passenger flow, which would cause passenger and/or train delays, and could even have safety implications.

1.3 The Railway Consultancy Ltd were therefore commissioned to provide an independent view of whether the space available for passenger circulation during construction works at Norreport would be sufficient to maintain a reliable S-Tog service.

1.4 Logically, there are two key questions. When station stop times at Norreport rise owing to the reduced circulation space,

- will the S-Tog be able to continue to operate the existing timetable at acceptable levels of performance? and
- will the passenger numbers trying to use the reduced number of exits be cleared before the next train arrives?

For the station to function satisfactorily, both of these conditions have to be fulfilled, with or without other management actions. This report is therefore focussed on obtaining answers to these questions.

1.5 A number of phases of construction work are proposed at Norreport. The most critical of these are the periods (understood to be of 3- and 6-months' duration) when the station will be split in two. Two separate stations will function, each serving trains travelling in one direction only. Each will only have sufficient platform length available to accommodate four carriages, with passengers in other carriages unable to alight. Since the other phases of work provide more capacity than this, we have concentrated our efforts in analysing this period; this is the 'worst case'.

1.6 Our first step has therefore been to investigate passenger flow conditions in Copenhagen, and hence to estimate the time required for passenger movements on and off trains, and in and out of Norreport station during the construction works (see section 2). We have then looked at a wide variety of operational issues (including timetabling) which might be used to mitigate the impacts of increased station stop time (see section 3). Our conclusions are contained in section 4.

2 Passenger Flow

The Logic of Our Approach

2.1 For Norreport station to be considered operable during the construction works, one has to ensure that all passenger movements between trains and the street (and vice versa) can be accommodated safely. If any part of this chain of movements does not work, the station fails the test of operability. We have therefore examined boarding and alighting from trains separately from the times taken to enter and leave the station. Preceding these sections are introductory sections on demand levels at Norreport, and passenger flow modelling in general.

Demand Levels

2.2 Passenger demand data at Norreport has been derived from 20-minute counts conducted on the first Thursday in November 1999, from which estimates of per-train movements have been made. Clearly, we need to clarify whether these figures are appropriate figures against which to test station performance.

2.3 Demand for a railway varies on a day-to-day basis for all sorts of reasons, including seasonal and weekly work patterns, and daily weather variations. Whilst DSB have advised us that overall monthly S-Tog demand varies by +13%/-22%, we understand that peak passenger demand is rarely more than 5% higher than in November, although weather variations also impact on traffic levels by 5% (even in the Winter). We have therefore assessed the operability of the station on a figure 10% higher than the demand figures might directly imply. Although this covers many days in which demand is higher than average, it should be noted that it is not a ‘worst case’ scenario, for which contingency arrangements may need to be made.

2.4 Passenger demand over the last few years has not varied a great deal. In addition, a slight downward trend in demand caused by increased car ownership and office dispersal out of central Copenhagen is expected to be balanced by factors such as increased road congestion and improved service performance. Current demand levels can therefore be assumed to continue throughout the three years of metro construction works.

2.5 Our surveys included counts of passengers at the critical door, from which we can estimate the total number of passengers at all doors. From this, we noticed that the published figures are 30% higher than the measured loads in the second week of January. This means that if a solution can be found to station operation, it is very robust in respect of the demand which might be placed upon it.

Passenger Flow Models

2.6 There are a number of models used internationally for estimating passenger flow in railway situations; the PEDROUTE model marketed by Halcrow Transmark has already been used for planning parts of the Copenhagen metro, including during construction works. However, it is the underlying relationships which are of critical importance here, and these largely stem from work by London Transport OR Note 89/18 (London Transport, 1989). Further work has been undertaken in this area by The Railway Consultancy Ltd, for the proposed London Crossrail project (Railway Consultancy, 1996), and in internal research.

2.7 The key relationships from LT's work are dependent upon a combination of passenger flow and vehicle characteristics. The important variables were found to be:

Passenger Flow Variables

A = number of alighting passengers from the critical door

B = number of boarding passengers at the critical door

T = number of through passengers in the critical vestibule

V_c = vestibule capacity (assuming $0.14m^2$ per passenger)

Vehicle Characteristics

DA = door aperture (net of any grab poles etc.) (m)

S = standback space in metres, per doorway

EDW = effective door width

D = door width factor (= EDW of LUL 1967 tube stock/EDW of rolling stock under examination)

2.8 The relationships derived using these variables were:

$$\text{Alighting time} = \{1.5*\{1+(0.9*T/V_c)]*A^{0.7}\}*DW$$

$$\text{Boarding time} = \{1.3*\ \{1+(0.8*T/V_c)]*B^{0.7}\}\ *\ DW$$

$$\text{Interaction time} = 0.027\ *\ A\ *\ B$$

$$EDW = DA + 0.7112*(1-e^{(S/0.7112)})$$

However, subsequent work by The Railway Consultancy Ltd (1996) has suggested slightly higher power functions for the A and B terms.

2.9 We surmised that if we could calculate from these equations the expected boarding and alighting time, together with the flow rate expected by passengers entering and leaving the platform, this would provide an independent estimate of the station stop time required at Norreport during the construction works. However, because it cannot be safely assumed that parameters are internationally transferable, we undertook to carry out some surveys in Copenhagen, to compare Danish passenger flow rates with British ones.

Train Service Surveys

2.10 We carried out two train service surveys at Norreport, one in each peak period. Detailed information collected included the time taken for different elements of station stop time, and the number of passengers involved in various movements, at the critical door.

2.11 Our surveys showed that station stops are currently averaging up to 30 seconds. Around 12 seconds is needed for passenger movements, and 5 seconds for opening and closing the doors. This leaves a further 11 seconds, which was largely being taken up by the time between the last passenger movement, and the time of initiating the door close procedure (we term this “driver delay time”). Although, for safety reasons, this figure cannot be reduced to zero, a figure of over 5 seconds is high in our opinion, and leaves room for improvement. It should also be noted that the observed figure is considerably higher than that assumed by DSB (7.5 seconds).

2.12 Significantly, the delay between the last passenger movement and the door initiation procedure was as high as 25 seconds in some cases. This should not have been because drivers were awaiting the correct departure time (since the service was running slightly late at these times), nor was it due to drivers facing adverse signals. The impact of reducing these longest station stop times significantly should not be under-estimated.

Boarding and Alighting Time

2.13 The boarding and alighting rates measured at Norreport ranged between 0.7 and 1.2 passengers/second respectively. This compares well with data from various other cities as set out in Table 2.1. Alighting rates were considerably higher than boarding rates in the a.m. peak, where alighting was the dominant flow, whilst boarding rates were slightly higher than alighting rates in the p.m. peak.

City	Station	Platform	Survey	Alighting	Boarding	Notes
		Id	Date	Rate	Rate	
				(pass/sec)	(pass/sec)	
Hong Kong	Mongkok	Tseun Wan Sb	24/6/96	0.36	0.60	trains very full
Lisbon	Baixa Chiado	Caravela Line, Nb	31/8/98	0.90	0.91	
London	King's Cross	Victoria Sb	8/5/96	1.00	1.01	
London	Clapham Junction	Sth Cent locals Sb	5/12/96	0.85	0.82	large step
London	Bank	Northern Nb	14/5/96	1.26	1.12	
Mexico	Pino Suarez	Pantitlan	11/2/99	1.14	0.74	trains full
Oslo	Jernbanatorget	Eb	14/4/99	0.77	0.58	driver compt blockage
Paris	Chatelet-les-Halles	Line A Eb	4/11/98	1.26	0.93	
Paris	Chatelet-les-Halles	Line D Sb	3/11/98	0.74	1.13	double-deck stock
Net boarding time excludes boarders boarding before all alighters have alighted						

Table 2.1. Passenger Boarding and Alighting Rates (pass/sec)

[Source: Railway Consultancy Ltd datasets]

2.14 The data calibrated easily against our existing work on boarding and alighting rates, with estimated passenger movement times of 12.0 seconds comparing well against actual times of 11.8 seconds. We therefore feel confident in estimating the increase in passenger movement (boarding and alighting) time which would be expected under different conditions. Moreover, our results are consistent with those calculated in PEDROUTE by Halcrow for KHRAS, provided that the latter are adjusted to reflect the fact that passenger movements are not equal across all the doors of a train.

Impact on Station Stop Times

At present, the S-Tog line through Norreport has an effective signalled headway of around 80 secs (comprised broadly of 20 secs station stop time, 20secs for one train to leave the platform, 20 secs for the signal to clear, and 20 secs for the next train to arrive at the platform). This gives a theoretical capacity of 45 trains per hour (tph), as against a maximum timetabled service of 27tph. However, this difference is required for coping with random events (e.g. passenger movements) and operational reliability. It must also be able to cope with any increase in station stop time caused by the construction works at Norreport.

Currently, the service continues to operate successfully because the actual station stop times at Norreport are around 30 secs (as the results from our survey demonstrate). This 1eaves a margin of around 50 seconds per train as recovery time (=80-30). Clearly, if this latter were reduced significantly because station stop times rose, and if the margin provided by the occasional timetabled 4-minute gaps in service were insufficient to recover the service, the whole service could be thrown into disarray.

2.17 Having calibrated the results of the train service surveys against previous work of ours, it was possible to provide an independent estimate of the increase in station stop time likely to occur during construction works at Norreport. They show that we would expect average station stop times to increase by about 11 seconds to 41 seconds when only the reduced platform area is available, and if no other action were to be taken. This suggest that it is quite feasible for the station to cope with the increased passenger flows per train door.

2.18 However, train loads are not even. To be quite sure that problems will not arise, we need to examine the worst case, which was a station stop of 59 seconds caused partly by a defective door on a train of 1996 stock. Double the demand here would have generated a station stop of 1 minute 37 seconds; we should allow 1 minute 40 seconds for a typical busy day. This would clearly lead to trains blocking back, because this exceeds the one minute the service can cope with (20 seconds assumed station stop time plus 40 seconds recovery). However, the next longest station stop under the proposed conditions would have been only 66 seconds, which causes only a minimal delay of six seconds.

2.19 Moreover, the preceding argument is based on the assumption that any increase in station stop time due to increased passenger flows results in a net increase in station stop time. We do not believe this assumption to be valid. In particular, we believe that it should be possible to improve on current performance by reducing the time taken by drivers to initiate the door close procedure, once all passenger movements have been completed. Our surveys of 79 trains showed an average 'driver delay' of 11 seconds, which is well above what might be reasonably expected, even with drivers conscientiously watching for passengers fouling the doors. We estimate that 5 seconds can be reduced from existing station stop times by doing this; alternatively, this time can be used to permit further passenger movements *without increasing station stop time*.

Stop Times at Other Stations

2.20 There is a perceived potential for station stop times to rise at the stations immediately before Norreport, as passengers ensure that they are in the correct part of the train. DSB's estimate of this is 12 seconds, but this is well within the recovery margin of any Central area station (see para. 2.16). Moreover, we believe that the actual figure should be negligible, if the measures to mitigate this, as set out in section 3, are adopted. In addition, there are three other factors which reduce the likelihood of this being a problem. First, not all passengers will attempt to change carriages during the same station stop (some passengers are likely to attempt this at an earlier opportunity). Secondly, some passengers will merely transfer to the following train which, in the Central area, follows within a few minutes. Lastly, for Northbound passengers, Kobenhavn H is the obvious place to change (rather than Vesterport), because trains are scheduled to spend 60 seconds there, and so additional dwell time is unlikely.

Peak Passenger Flows at Norreport

2.21 The situation at Norreport is that significant numbers of passengers leave the station in the morning and enter it in the evening. During the construction works, the station will effectively be split into Northbound and Southbound stations. If two trains arrive simultaneously in the morning peak, passengers will simultaneously leave the station – but by completely different halves of the station. They should have relatively little difficulty in passing the passengers attempting to enter the station and to board trains, since there are relatively few of these. However, the morning peak is still an issue because of the requirement to be able to evacuate the station safely (either in normal conditions, or in emergency).

2.22 In the afternoon peak, however, the position is somewhat different. Not only are the numbers of peak passenger movements per train higher, but so are the contra-peak movements. Although we have not analysed the impact of contra-peak movements in full detail, such movements are more onerous to cope with than are the same number of additional movements in the peak direction, as conflicts between opposing passengers occur. We have however taken account of these passenger flows in our calculations. The afternoon peak is therefore clearly a key period of concern, although it does have the advantage that passengers can be kept out of the station if overcrowding occurs.

Passenger Flow Rates within Stations

2.23 So far, we have only calculated the time required for boarding and alighting. However, a key issue is clearly the rate at which passengers enter and leave the station. To estimate this, we have taken recourse to the passenger flow values recorded in Fruin's seminal work (1971), which has been widely quoted elsewhere (e.g. by Harris & Godward, 1992). However, it should be noted that maximum passenger flow conditions do not occur in situations of free circulation (Fruin's level A), but where there is some congestion.

2.24 Passenger flow rates increase from those recorded in free-flow conditions to those recorded in busy conditions (Fruin's level E) before breaking down completely in crush conditions (F). Walking speeds fall throughout the range A to F. Common practice in the UK is to plan for passenger densities of no more than level D, which gives flows of roughly 60 pass/m/min on the flat, and 40 pass/m/min on stairs. In these conditions, passenger speeds are around 60m/min on the flat, and 30m/min on stairs. We have assumed that these figures (originating from North America, but widely used in Britain) are indeed appropriate in Denmark.

2.25 In no cases did current trainloads of alighting passengers take more than 50 seconds to clear the Northern staircase in the a.m. peak after train arrival, even when Southbound and Northbound trains arrived simultaneously. This is a useful analogy since, in the disrupted situation, it is expected that double the number of passengers will be trying to leave the Northbound train, but that the Southbound train will be calling at a separate part of the platform. However, the minimum headway is 80 seconds so this level of demand clearly is not a problem.

2.26 Having ascertained what the relevant passenger flow rates are, it was then possible to estimate the "platform clearance" time i.e. the time taken by passengers to clear the platform. It must be

remembered in passenger flow work that the critical direction of passenger flow is exiting from stations (for safety reasons). Although passengers can always be held at street level and prevented from entering a station if it gets overcrowded, once passengers have alighted from a train, they must be able to leave the station.

2.27 Data provided by ScanRail showed that the busiest trains arrive in the period between 07:40 and 08:00. Here, the expected maximum flow of passengers is 2018 people attempting to leave the station. Nevertheless, to allow for day-to-day variation, we consider it prudent to examine the case for 10% more than the maximum currently estimated i.e. 1.1 x (245 alighters and 34 boarders expected at 07:58)=304 passengers.

2.28 The remaining platform area is 3m wide. At a flow rate of 60 pass/m/min, this is expected to take 80 seconds to clear. This time should be compared to the minimum headway (between one train departing and the next train departing) of 80 seconds (theoretical) and 120 seconds (timetabled). Equivalent calculations for egress by stairs (assuming the second North-end staircase is indeed constructed) are 35 pass/m/min and 91 seconds.

2.29 For the station to function smoothly, and for delays not to accumulate, the maximum passenger time must be below 120 seconds (the timetabled headway) plus a margin. This analysis shows that this is indeed achieved, with 29 seconds (120-91) being the margin. In our view, this is ample for maintaining a reliable service in normal conditions, thereby confirming PEDROUTE analysis. Importantly, the platform is usually expected to be clear of one train's passengers before another one arrives.

Train Service Disruption

2.30 The platform area available during metro construction works is clearly less than that at present. The impact of this reduced area is to reduce the number of passengers who can be held at platform level. During periods of train service disruption, passengers do congregate at this level, having arrived for a train which is delayed.

2.31 Assuming that passengers arrive on the platform about 7 minutes before their train is due to depart, at present, the station can cope with a 'trainless' period of around 18 minutes; at this time, the platform would be completely full. This period is expected to fall to around 8 minutes. Management actions to prevent this position becoming dangerous are therefore likely to be needed more quickly (and hence more often) than at present. A number of potential courses of action are available to prevent this phenomenon ('station control') even becoming necessary in the first place, and these are discussed in section 3 of this report.

Emergency Evacuation

2.32 We are satisfied with the results of PEDROUTE tests showing that the time taken to evacuate a full station will be reduced during the period of metro works, from 8.8 minutes to a maximum of 7.2 minutes. This is because the area to be used for works is currently available for passengers, so the total passenger-holding capacity of the station will fall. However, the number of exits will be increased through the provision of the Northern temporary stairs. The emergency evacuation of the station will therefore be better during the works than in normal conditions.

Summary

2.33 Our conclusion on station stop times is that increases in passenger demand are not likely, in the normal course of events, to lead to increased station stop times of more than a few seconds. Larger increases may occur from operational problems (e.g. the defective door we witnessed) but these should be rare, and are within the current variation in service performance.

2.34 Our conclusion on station egress is therefore that the platforms can be cleared easily within the time allowed by the train service headway. The provision of an additional stairway at the North end of the station gives us comfort that clearing the station from normal operation is straightforward.

3 Operational Issues

3.1 The Copenhagen S-Tog service is run fairly effectively to provide a service of up to 27 tph through the core section between Kobenhavn H and Osterport. Although the network and train service pattern are quite complicated, investment in flying junctions, cab-based signalling and passenger loadings rarely exceeding 110% of seating capacity make the system easily manageable. However, like most urban rail services, it has its problems (e.g. in the level of small delays), and Norreport station will be a further problem during the construction of the metro. Logically, actions will clearly be required in order to maintain the current levels of performance during any such construction works; the key question is whether such actions will be sufficient to mitigate the impacts of the works. We would emphasise that, in the absence of further action to improve performance, the situation of declining performance described by DSB is likely to be fulfilled; positive action will be required.

Existing Performance

3.2 Existing service performance is judged against a criterion of 95% of trains arriving at stations within 2 minutes 29 seconds of booked time. This is quite challenging in general terms, but is being achieved regularly in Copenhagen due to the systems' inherent advantages as set out above.

3.3 During our surveys, most trains ran a minute or two late at Norreport, but this is commonplace in a European environment. Only a couple of trains were out of their planned sequence.

3.4 However, our surveys at Norreport did highlight a number of areas where improvements could be made. First, late running in the Central area was acknowledged to be partly due to insufficient time being available in the timetable for this section.

3.5 Secondly, there are currently a number of temporary speed restrictions, having a greater effect than is allowed for in the timetable.

3.6 Thirdly, changing drivers at Kobenhavn H (including during the peaks) sometimes takes longer than the 60 seconds allowed.

3.7 Lastly, much of the equipment is not new (with rolling stock around 35 years old, and the signalling system 25 years old), and failures are increasingly common. Specifically, failures in the cab signalling system, requiring the use only of lineside signals, significantly increase headways. All of these have a significant impact on service reliability.

Future Performance

3.8 We understand that targets for future performance are higher than at present. This is due to the implementation of a number of infrastructure improvements (e.g. double-tracking of the Frederikssund branch) and the introduction (in due course) of new (and more reliable) rolling stock. We would support the view that increases in operational performance can be implemented.

Operational Solutions

3.9 There are many ways of improving the reliability of a rail service, should it fall below the acceptable level, and DSB have already identified many of these. Even when the problem is excessive station stop times, a number of measures have been found useful in the past. These include:

- passenger hurrying devices (whistles etc.);
- improved in-train and on-station announcements;
- staff training (delays prior to drivers initiating the door start procedure can be significant);
- timetable adjustments (e.g. varying stopping patterns) to improve the ability to recover from delays;
- increased station stop time allowances in the timetable;
- introduction of additional signals to reduce the run-out/run-in time;
- the re-ordering of passenger flows within stations; and
- the exclusion of some passenger groups or train services.

3.10 In addition, the situation at Norreport presents other detailed opportunities for improving the current performance, especially during the peaks. These include:

- a comprehensive briefing of drivers before the construction period, in order to obtain their active participation in mitigating the performance risks generated by the works;
- digital clocks to assist drivers' understanding of urgency (by reducing time between last boarder and door close initiation); supported by
- staff on each platform to dispatch trains with a baton and whistle;
- discouraging cycle users to use the station during the works (cyclists might reasonably be able to cycle to an alternative station);
- moving the ticket validators from the foot of the stairs to the concourse level (as these are causing passenger flow conflicts);
- attaching 'Do Not Alight Here' posters to the unusable parts of the platform;
- posters at all stations from one month before works start, advising that all passengers to/from Norreport should use the front four carriages of the train/platform;
- leaflet drops and newspaper advertising and local radio supporting this;
- 'military' or similarly-paced music being played over the loudspeakers to

increase passenger walking speeds;

- staff at concourse level to encourage passengers to wait away from the platforms until five minutes before trains are expected (notice of this procedure to be included on posters too);
- the additional Northern staircase;
- letting some trains run non-stop through the station; and
- discouraging drivers from re-opening doors to allow late passengers to board.

Those measures which we consider feasible are explained in more detail below.

3.11 To some extent, the best solution(s) varies with the location. However, our experience of dealing with these problems in other urban railway situations enables us to make a number of recommendations.

Station Works

3.12 We have assumed that the second staircase at the Northern end of the station will be constructed in time for the period of works. We believe this to be critical in ensuring sufficient egress capacity during the a.m. peak.

Timetable Adjustments

3.13 The timetable, although well-constructed, is actually quite complex. The creation of different stopping patterns inevitably leads to a deterioration in service performance after a small problem develops. It also requires small signalled headways along all the branch lines, right to the end, to enable fast and slow trains not to delay each other. If traffic grows, consideration may need to be given to simplifying the service pattern, because the reliability benefits will tend to exceed the disbenefits which may be caused to particular groups of passengers who currently have express services. We have carried out a number of studies of such issues, and have developed an operational performance model which we would be glad to apply to the S-Tog network.

3.14 In the morning peak, four slots through the critical central section in an 80-minute period are taken up by Ex services. These have the lightest loading of any peak service, being formed of only four cars. Between Solrod Strand and Kobenhavn H, the Ex appears to fulfil a useful role by relieving the preceding A+ and the following E services. North of Kobenhavn H, the potential benefits in terms of the network's ability to recover from delays seems, to us, to be greater than the value currently provided by these four trains. We therefore recommend the termination of these four Ex services at Kobenhavn H.

3.15 The implications of this course of action on platforming in the northbound S-Tog island platform at Kobenhavn H have been investigated. Termination of trains from the south at Kobenhavn H is facilitated by the two northbound tracks feeding an island platform with two faces. Termination of service Ex at the western face of the northbound island platform leaves margins of only 4 minutes ahead of the following E service. These could use the eastern face of this island platform in the 4-minute gap between northbound services C and B. Thus Ex services terminating in the western face would have the same 7-minute margin as the existing Bx services which also terminate in this platform. Peak hour occupation in the eastern face would be 18 minutes (30%) by 18 through trains and (assuming 3 minutes for a terminating train to unload, reverse and depart to the sidings), 24 minutes (40%) in the western face by 6 through and 6 terminating trains.

3.16 Recognising that this might cause some overcrowding problems North of Kobenhavn H, we noted that the service following the Ex (C) had only six cars. Based on the loadings of those C services which we observed at Norreport, that did not appear to be a problem. However, if any extra vehicles are available, one or more of the relevant C services could be increased to 8 cars, this minimising this risk.

3.17 We have also considered non-stopping some trains at Norreport. However, this would require quite a large number of passengers to change at the previous station. We therefore believe that the disbenefits of the additional dwell time at the previous station call would exceed the benefits of a train not stopping at Norreport. This is particularly the case because the critical line section is in fact between Vesterport and Kobenhavn H, and not at Norreport.

3.18 We recognise that changes to the timetable take some time to introduce. However, the introduction of an additional half-minute to running times in the central area would help the service operate smoothly. Even if this could not be introduced until 2002, it would still provide a benefit (in terms of service reliability) for the last year of works at Norreport.

3.19 At present, the timetabled service presents trains in flights in the Central area. This is understood to present opportunities for running empty trains in the gaps, but we are not convinced that this is a worthwhile benefit to offset against the performance disadvantages. We therefore considered whether it was possible to improve the performance of the flighted train service, without major alterations to the timetable. As the performance of flighted trains is heavily dependent upon the first train in the flight, it could improve performance if this were accelerated in some fashion.

3.20 One way of doing this would be to omit the stops at Vesterport (Northbound, services H+ and C) and Nordhavn (Southbound, B and B+), although trains would wait time at Osterport and Kobenhavn H respectively, so that the overall timetable structure was unaffected. A faster first train would tend to drag the subsequent trains through more quickly, and potentially improve performance. Despite the obvious passenger communication problems of non-stopping these trains at these stations, we would urge careful consideration of this proposal to improve capacity problems in the central area.

Information Activities

3.21 The public's ability to respond to any changes to their travelling arrangements depends on good early publicity. This has the added benefit of showing that DSB are anticipating the problems and positively managing the situation.

3.22 Publicity (which should be available one month before the closure occurs) should cover all platforms on the S-Tog system, inside the trains, and local newspapers and radio. It should highlight the restriction on platform length due to metro construction, and the consequent need at Norreport to alight only from the front four carriages. Passengers boarding at Norreport will have to use specific entrances for travel in each direction.

3.23 Publicity should also note that in the evening peak, passengers will be encouraged not to go down to the platforms more than 5 minutes before their train is expected to arrive. Suitable information systems will need to be made available to reassure passengers of the expected waiting time for their chosen service.

3.24 Poster-type information should also point out that time can be saved for everyone if passengers keep right on stairways, and don't attempt to join trains until all passengers wishing to alight at the relevant door have done so. This needs to be reinforced by 'Keep Right' signs at the top and bottom of the stairs at Norreport station itself.

3.25 During the period of the works, we would encourage all S-Tog *stations* to make frequent announcements that passengers for Norreport must travel in the front four carriages of any trains. Such announcements should also be made in all S-Tog *trains* well before they reach the stations on either side of Norreport, as well as at those stations (Vesterport and Osterport).

3.26 We understand that it is possible for passengers to open train doors using a button even when the driver has not released them. As a result, passengers could conceivably try to alight where there is no platform. Posters (advising, in red, 'Do not alight here') should therefore be stuck onto the side of the works area facing the track, in an attempt to minimise this possibility. In the longer-term, introducing a selective door opening facility (permitting drivers to release only some of the train doors) enables this type of problem to be reduced, if not eliminated.

3.27 During the period of construction works, each end of the station will have two potential exits. In both cases, one exit will be more visible than the other – although it may not necessarily provide passengers with a quicker egress. Either through posters on the platforms, and/or through announcements by staff on the platform or through public address, passengers need to be encouraged to use the exits in proportion to their capacity. This is particularly an issue at the South end of the station, where the exit which is easier to see is the smaller one.

Staff

3.28 Drivers need to be encouraged to make up time when they are running late, although this should not, of course, prejudice safety. We believe, however, that there is potential for station stop times to be reduced by a few seconds at each of the central area station, and even this could make a noticeable impact on the tendency of the service to degenerate. To help drivers achieve this, we recommend the installation of digital clocks (with seconds displayed) at the ends of the platforms at all central area stations. These should show consistent times, perhaps transmitted from a central control room. Our observations revealed that even clocks on different platforms at Kobenhavn H showed slightly different times (neither of which we believe to be within one minute of the correct time), whilst the time at Farum was different again.

3.29 Additional platform staff (at least one per platform) will be required at Norreport for the duration of the works. The main responsibility of these staff will be to dispatch trains (we suggest using a baton and whistle), thereby aiding the driver, for whom the platform monitors will not be able to provide the assistance that they currently do. As we understand that DSB does not currently have any crowd control staff assigned to S-Tog services, these staff will have to be specially trained to take pro-active decisions *before* they think a problem is going to occur.

3.30 Additional staff (one per entrance in offpeak periods, two per entrance in the peaks) will be needed in the concourse areas. Their functions will be to segregate entering and exiting passengers on the stairs, in making announcements about waiting (perhaps through a megaphone) and in giving information.

3.31 During the peaks, we also recommend that one member of staff is positioned outside each entrance to the station. Their main function will be to provide information to passengers, to ensure that passengers enter the correct part of the station.

3.32 All the staff noted above need to be easily identifiable to passengers e.g. through wearing distinctive clothing (e.g. high-visibility orange vests).

Station Operation

3.33 During the period of the works, passengers will inevitably have less space on the platforms. It is therefore important that factors which work to increase space are countered. For instance, posters reminding passengers that bicycles should not be carried in the peak periods would be appropriate. Given the underground nature of Norreport station, and the works going on there, we would also recommend that smoking is not permitted during the period of the works; this will tend to let people stand closer together, as well as having fire risk and health benefits.

3.34 Although we do not believe that it is practicable to ban prams and wheelchairs from the station, it does seem appropriate for publicity to note that station access will be more difficult during the works. We understand, for instance, that lift provision will not be available at all times to both ends of the station. This will dissuade some marginal users of the station who

might otherwise have had difficulties and created delays for themselves and others.

3.35 Although the passenger boarding and alighting rates measured during our surveys were satisfactory, encouraging these to be maintained or improved seems a sensible course of action. We therefore recommend playing military-style or similar suitably-paced music over the public address system during peak periods.

3.36 Lastly, we observed that the ticket validators at the foot of the stairs were causing passenger movement conflicts. If these could be moved to the concourse or street levels (even just for the period of metro works), this problem would be avoided.

Summary

3.37 Although we believe the operation of Norreport station during metro construction works to be entirely possible and safe, we acknowledge that conditions vary on a day-to-day basis. We have therefore recommended a range of operational measures above which, taken together, should ensure that the service operates without undue difficulty in almost all conditions. The majority of these had already been identified by DSB management, but without the confidence that they would indeed deliver the improvement in station performance needed. However, it would also be sensible for DSB to have a number of contingency plans relating to extreme situations which might occur (especially in the central area). We would be happy to discuss appropriate principles for developing emergency timetables.

3.38 We do acknowledge that some of these items may be considered contentious, and that cooperation from all S-Tog staff members (including drivers) is essential. However, we believe that the measures suggested are indeed realistic and reasonable, and would expect that S-Tog management will be able to implement them.

3.39 The DSB report implicitly assumes that any problems at Norreport add to the existing operational problems (such as those noted above in paras. 3.4-3.7). We challenge this view on two counts. First, we do not think that station stop times at Norreport will rise sufficiently to create a major problem. Secondly, it is incorrect to assume that any such problems will necessarily be net additions to the level of delay on the system, because other measures are available to reduce these other delays.

3.40 We are also not convinced that the relationship derived in the DSB report is sound. It appears to assume that 90% punctuality is a function of current station stop times at Norreport, including 7.5 seconds of what we term driver delay time (the time between last passenger movement and the start of the door close process). First, the 90% punctuality achieved is a function of many factors, not just the performance of Norreport station. Secondly, the relationship appears to be calibrated on too small a value for driver delay time. Our measurements showed that driver delay time was 11 seconds. Reducing this would improve punctuality.

3.41 However, the S-Tog system clearly will have less slack during the period of Norreport station works than it does at present, although the various operational measures we have recommended will make life easier for DSB managers. Nevertheless, it might be helpful for a small group of those managers responsible for day-to-day operation to visit somewhere where daily conditions are worse than at Norreport. One such appropriate place could be London; we would be happy to assist in arranging a technical visit for DSB staff to stations such as Victoria.

4 Conclusions and Recommendations

4.1 Station stop survey data was collected, from which current boarding and alighting rates at Norreport were found to be 0.7-1.2 passengers/second at the critical door respectively. From this, we managed to reproduce the existing average station stop time elements for passenger movements. To allow for the future restricted conditions during metro construction works, and for day-to-day variation, we expect the passenger flow element of the stop time to rise by 11 seconds. We therefore recommend that 22 seconds are allowed for boarding and alighting, implying 35-40 seconds as typical station stop times.

4.2 Within the 60 seconds available within the timetable for station stop time and recovery time, boarding and alighting times are expected drive station stop times to a maximum of 66 seconds during metro works. Although we can conceive of situations in which longer station stop times occur, these are not primarily dependent upon Norreport, but upon other incidents (e.g. train door problems), and we believe that they can be managed safely.

4.3 Passenger flow rates were observed at Norreport, and then applied to the station as it will be during the construction works. This implies that, at the height of the morning peak, it will take 91 seconds for all passengers to disperse from arriving trains, as opposed to around 50 seconds as observed. However, the theoretical minimum headway is 80 seconds and the average timetabled headway 120 seconds, so this should not be a problem.

4.4 We therefore believe that the station at Norreport can remain open during metro construction works. Without further actions, however, there is a danger that problems could occur from time to time. In order to ensure that the service remains reliable in almost all situations, we therefore recommend a range of management actions as set out in section 3 to improve operations. Although individually modest, the collective effects of these actions will be sufficient safely to maintain current performance levels.

4.5 Although we have addressed many of the most important factors affecting S-Tog performance in the Norreport area in this report, there remain a range of other operating issues associated with the S-Tog more generally. We would be happy to assist any of the industry participants at Norreport (the Ministry of Transport, DSB, Banestyrelsen etc.) in investigating these issues further.

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