

Systematic analyses of train run deviations from the timetable

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Abstract

On Rail Net Denmark's network, a Delay Report is created if a train is delayed more than 4 minutes and 59 seconds. All delayed trains are attached to a Delay Report describing the cause and consequences of the incident. The Punctuality Reporting System focuses on the causes of initial delays and much effort is spent analysing those. However, until now, much less effort has been spent on systematically analysing the train running themselves, extracting information on where in the network trains are delayed and which trains are delayed. After a description of the present delay follow-up system and its systemic weakness (section 3 and section 4), a toolbox of analytical methods developed to deal with this weakness is presented. The methods use a percentile approach aggregating either deviation from the timetable at measuring points or difference in deviation between measuring points. The aim is to identify the measuring points where the largest delays occur for individual trains and train systems so that the parties responsible can act. After a description of the methods (section 5), examples of the new types of analysis are demonstrated (section 6), e.g. identification of local speed restrictions which influence the punctuality, the worst performing trains and reasons for their delays. It is thus shown how new information can be extracted from the train run history. The percentile approach is orthogonal to the classical analysis of cause of delay above a threshold and should not be regarded as a substitute but as a valuable supplement. One of the reasons for the successful implementation is a general shift in the corporate mindset within Rail Net Denmark towards a higher KPI focus.

Keywords: railway operations, systematic follow-up, delay, punctuality, service quality, robustness, realised operations, organisational implementation.



1 Introduction

The results of measurements depend on how the measuring is carried out as well as on how data is aggregated. Traditionally, all analysis of train delays within the Danish railway sector has been based on the notion of affected train, which are trains delayed more than 4 minutes and 59 seconds or cancelled. This is the method recommended by UIC [1]. Within this definition, a train is either affected or it is punctual. Thus lots of information about delays smaller than the threshold of affected trains has not been systematically analysed - until now.

2 Operation of Rail Net Denmark in brief

As in many other EU countries the railway sector in Denmark has been divided into separate Infrastructure Managers (IM) and Railway Undertakings (RU). Rail Net Denmark is the main IM in Denmark and five major passenger RU operate on the network of Rail Net Denmark. Passenger transport is far more important than freight transport in Denmark, which is limited to three major freight RU operating mostly transit trains between Sweden and the European continent.

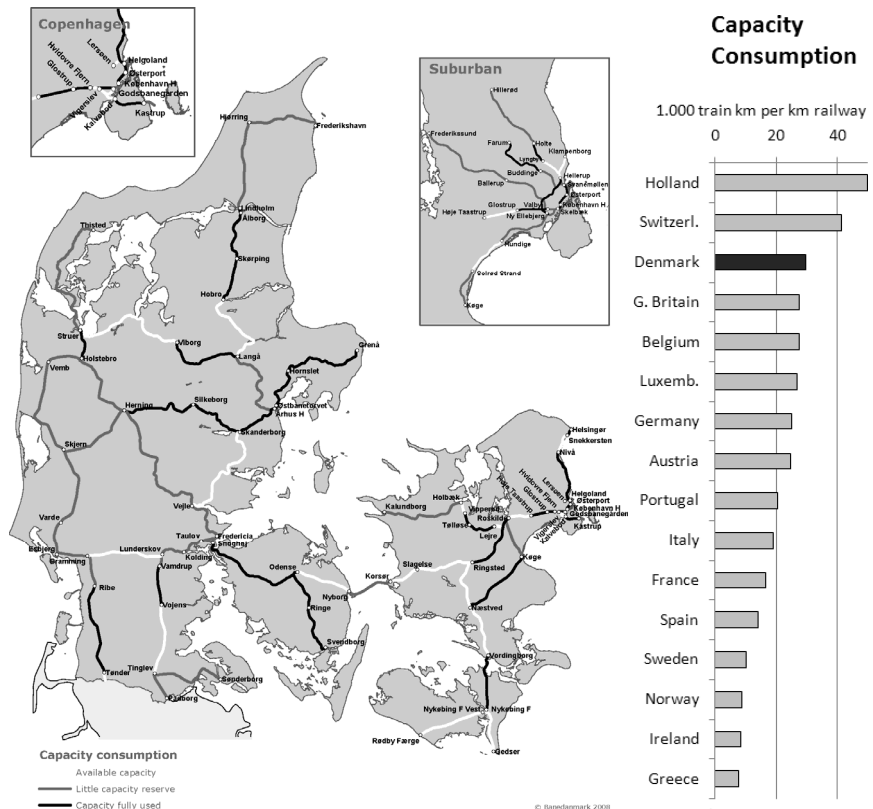


Figure 1: Capacity consumption in Denmark in 2008 [2] and in Europe [3].

The length of Rail Net Denmark's network is 2,220 km of which 45% are double or quadruple track. On the mainline network, approximately 1,400 trains are operated daily of which approximately 70 are freight trains. The length of the Copenhagen suburban railway network is 169 km and approximately 1,100 trains are operated daily on this network [4].

The network of Rail Net Denmark is one of the most densely used in Europe following Switzerland and the Netherlands (cf. figure 1). Using the definitions of UIC leaflet 406 [5] in Figure 1, the capacity consumption is at the limit or near the limit on parts of the network. Such intense usage of a railway network makes it prone to delays and initial delays may very well cause consecutive delays. This also raises the risk that minor timetabling faults or local temporary infrastructure shortcomings have larger consequences. Thus detailed and advanced analysis of train delays are important in order to achieve a reasonable punctuality.

3 Available data: how delays are measured

The backbone of the Punctuality Reporting System of Rail Net Denmark is train position data from the digital Traffic Management Systems (TMS), which cover 70% of the length of the network. The data collected are arrival times to and departures time from measuring points, which are stations and halts. The arrival time is defined as the time when the platform track circuit is occupied and departure time is defined as the time when the next main track circuit is occupied. On the parts of the network where older and less capable TMS are used, arrival and departure times are entered manually and only for the main stations. Approximately 330 measuring points exist of which 166 automatically collect data from the TMS. Based on this information as well as the timetable, RDS creates a train run history (Table 1).

Table 1: Train run history.

TOG	FORSTE_KOREDATO	STAT	MLD_TYP	PLANTID	MLD_KAT	AFVIGELSE	MELDINGSKILDE	TRA_ARS	ARS_TOG	TEKST	DRAP
136	23-07-2008	LIH	U	23-07-2008 11:00	K	0	INDDAT2				
136	23-07-2008	AB	I	23-07-2008 11:06	K	0	INDDAT2				
136	23-07-2008	AB	U	23-07-2008 11:10	K	-17	INDDAT2	920			941815
136	23-07-2008	EH	G	23-07-2008 11:23	K	-15	INDDAT2				
136	23-07-2008	SØ	I	23-07-2008 11:32	K	-15	INDDAT2				
136	23-07-2008	SØ	U	23-07-2008 11:33	K	-15	INDDAT2				
136	23-07-2008	HB	I	23-07-2008 11:50	K	-13	INDDAT2				
136	23-07-2008	HB	U	23-07-2008 11:51	K	-13	INDDAT2				
136	23-07-2008	RD	I	23-07-2008 12:07	K	-11	INDDAT2				
136	23-07-2008	RD	U	23-07-2008 12:08	K	-11	INDDAT2				
136	23-07-2008	LG	I	23-07-2008 12:16	K	-12	INDDAT2				
136	23-07-2008	LG	U	23-07-2008 12:17	K	-12	INDDAT2				
136	23-07-2008	AR	I	23-07-2008 12:47	K	-8	INDDAT2				
136	23-07-2008	AR	U	23-07-2008 12:54	K	-8	INDDAT2				
136	23-07-2008	SD	I	23-07-2008 13:09	K	-8	INDDAT2				
136	23-07-2008	SD	U	23-07-2008 13:10	K	-8	INDDAT2				
136	23-07-2008	HED	U	23-07-2008 13:34	K	-5,17	DWH				
136	23-07-2008	VJ	I	23-07-2008 13:42	K	-3,17	DWH				
136	23-07-2008	VJ	U	23-07-2008 13:44	K	-4,83	DWH				
136	23-07-2008	BK	G	23-07-2008 13:53	K	-1,5	DWH				
136	23-07-2008	FA	I	23-07-2008 14:01	K	-0,83	DWH				

If trains are delayed by more than 4 minutes and 59 seconds at a measuring point (2 minutes 29 seconds on the Copenhagen Suburban network) the dispatcher creates a Delay Report in the Punctuality Reporting System describing the delay in details (Figure 2). All trains delayed or cancelled because

of the incident are then attached to the report, both those initially delayed and those consecutively delayed. This process is done manually and relies on the skill and experience of the dispatchers. The trains attached to a report are described as affected trains.

The Delay Reports are coded similar to the UIC leaflet 450-2 [1] and the Delay Reports also receive a responsible party, which is the party that could have prevented the error. Within Rail Net Denmark, the delay code structure is such that a Delay Report unambiguously can be linked to a business unit.

The screenshot shows a software interface for a delay report. The title bar reads 'statistik / bearbejd driftsrapport'. The main form contains the following fields and annotations:

- Time of incident:** Points to the date '26.04.2010'.
- Incident id:** Points to the 'Driftsrap. nr.' field with value '1105637'.
- Headline:** Points to the 'Indtrædt' field with value '26.03.2010 18:15'.
- Station:** Points to the 'Station' field with value 'RD'.
- Cause (code):** Points to the 'Årsagstype' field with value '711'.
- Party responsible:** Points to the 'Ansvarlig' field with value '1276'.
- Train no:** Points to the 'Tognummer' field with value '3160'.
- Rolling stock no.:** Points to the 'Materiellnr.' field with value '4006'.
- Start time of recovery:** Points to the 'Starttid genopretning' field.
- In-depth description and follow up:** Points to the 'Opfølgning/svar' table.
- Classification of fault:** Points to the 'FATAL' dropdown menu.
- Corrective Maintenance:** Points to the 'Vagt tilkaldt' field with value 'AR-JBTS'.
- Dispatched:** Points to the 'Tilkaldt kl.' field with value '26.03.2010 19:15'.
- Arrived:** Points to the 'Vagt ankomst kl.' field with value '26.03.2010 20:25'.
- Fault corrected:** Points to the 'Klarmeldt kl.' field with value '26.03.2010 21:10'.

The 'Opfølgning/svar' table contains the following data:

Anmeldt af:	Anmeldt tidspkt:	Teksttype:	Tekst:
AR-JBTS	26.03.2010 18:16	Systemoprettet	Status ændret fra (Ingen) til ÅBEN.
AR-JBTS	26.03.2010 18:16	Fejlrapport til FRF	3160 fik ATC nødbremse 804 i km. 177.2 1.hs FP-RD
AR-JBTS	26.03.2010 19:10	Hænd.besk.	6464 fik ATC nødbremse 804 ved 2. balise før uvk
AR-JBTS	26.03.2010 21:49	Hænd.besk.	72 fik ATC nødbremssning 804 ca. i km 177.8 kl. 21
RDS	26.03.2010 03:43	Systemoprettet	Status ændret fra ÅBEN til LUKKET.
010157KBHA	07.04.2010 09:40	Opfølgningsbesk.	Fejlbesk.: Fejl i balise BFS 1177v defekt styrebøger. Ifejlret.: Nyt styr

Figure 2: Delay report.

4 Classical threshold approach to delays analysis

The primary Key Performance Indicator (KPI) for punctuality within the Danish railway sector is affected trains. Since a responsible party for all affected delays can be indentified through the Delay Reports, a complete KPI system is formed on this basis [6]. Each year, targets for the number of affected trains that Rail Net Denmark is permitted to delay are defined by the Ministry of Transport. Internally in Rail Net Denmark, these targets are broken down into a Punctuality Budget which describes how many trains may be affected by each business unit.

This method has been used for many years, has gradually been perfected and is considered well implemented and well functioning. With some RUs similar targets have been defined including bonus-malus schemes.



Although the system based on affected train is successful, it has some disadvantages:

- If a train has been gradually delayed, it is attached to the Delays Report describing the cause of and the circumstances surrounding the largest of the delays. Information about the smaller delays is thus lost.
- Minor delays, that never pass the 4 minutes 59 seconds threshold, will go unnoticed using the method of affected trains.
- The focus of the Delay Reports is on where the initial delay occurred and its root causes. There is no focus on where the consecutive delay occurred.

Thus, systemic minor delays with common causes may never be examined, just as the vulnerability of parts of the timetable may never be exposed since there may be many different reasons for the initial delay. Lowering the threshold for Delay Reports will not solve these problems. This will lower the consequences, but require an unrealistic amount of manpower from the dispatchers as well as they may have difficulties determining the actual causes of smaller delays.

Alternative methods such as delay minutes are not used since sufficient detailed passage times can only be obtained from parts of the network. Furthermore, cause of delay is only given to delays of more than 4 minutes and 59 seconds (2 minutes and 29 seconds on the Copenhagen Suburban network).

5 New percentile approach

To harvest the information about delays that the classical threshold method leaves out, a percentile approach is used on the train run history. For all trains or groups of trains, percentiles of the timetable deviations are calculated for all measuring points over a given period of time (example in Table 2). Alternatively, percentiles are calculated on the timetable deviations between two measuring points (example in Table 3).

The distribution function for delays of specific train number is given by

$$F(x_{r,n}) = p_{r,n} \quad (1)$$

where r is the measuring point, n the train number

The corresponding p -percentile function is

$$F^{-1}(p_{r,n}) = x_{r,n} \quad (2)$$

The distribution function on group of train numbers is given by

$$F(x_{r,n_{grp}}) = p_{r,n_{grp}} \quad (3)$$

where r is the measure point, n_{grp} the group of trains

The corresponding p -percentile function is

$$F^{-1}(p_{r,n_{grp}}) = x_{r,n_{grp}} \quad (4)$$

Since eqn. (1) only calculates the deviation for a specific train at a specific measuring point over time, input equals output if the function is only run with

dataset of one day. A consequence of additional data on which the percentile in eqn. (2) is calculated is that if a single train has a large deviation from the other or if a large deviation exists between the days, this has a greater impact on the result in eqn. (1) than in eqn. (2).

Table 2: Example of meridian on delays at measuring points.

Train type	Train	Station	Measurement	50% Percentile
EN	482	KH	Arrival	-5 min
IC	132	KH	Arrival	1,17 min
IL	16	KH	Departure	-3 min
ØK	1345	KH	Arrival	0,17 min
ØK	1345	KH	Departure	-0,5 min
ØK	1345	SÅ	Arrival	0,67 min
ØP	2046	GÆ	Departure	-0,33 min
ØP	2046	KH	Arrival	0,5 min
ØP	2046	SQ	Arrival	0,33 min
ØP	2046	SÅ	Departure	0,67 min

Table 3: Example of percentiles for deviation between two measuring points.

Train type	Measurement	Percentile				
		50%	70%	80%	90%	95%
IC	SG - SG: station	0,67 min	0,83 min	1 min	1,17 min	1,66 min
L	FJ - SO: line	1	1	1,17	1,17	1,34
IC	RG - KY: line	-1	-0,83	-0,67	-0,5	-0,17
L	SNO - MD: line	-0,83	-0,83	-0,5	0,17	1,33
IC	SPR - KØ: line	-1	-0,84	-0,83	-0,5	-0,16

Different percentiles have been used and although all contribute with relevant information, two have proven to be more useful than others: the 50% percentiles, since this is the meridian and the 90% percentile since this is the percentile where the poorly performing trains tend to emerge. Comparing the 90% percentile with the 50% percentile gives an indication of how much worse the poorly performing trains run.

For the reportings to yield meaningful data, no significant changes may have occurred to the timetable during the period of time examined. Thus the longest period it is possible to examine is the duration of the timetable. If the period examined is too long, issues that have been solved or become irrelevant may still be represented in the data and thus divert focus from present issues. If the period is too short, single events may have too much influence on the result. A guesstimate for the minimum period is a month depending on the number of trains examined and the aim of the analysis. For the majority of the reportings implemented, the optimal time period of evaluation is judged to be one month due to the operational environment that they are being used in.

The percentile approach requires accurate passage times with a high resolution at many measuring points. For many usages, the percentile approach is

thus only applicable on the parts of the network with automatic collection passage times.

6 Reportings and results

Based on the percentile approach, a number of reportings have been developed. They are all based on aggregation of the percentile values using common averages. Common to all these reporting is that they highlight areas which should be analysed in depth by other means before corrective actions can be taken. In many cases, the issues found are well known problems for which no easy solutions are available. The reportings do however quantify the operational impact of the issues found in relation to each other.

6.1 Worst performing trains

The best implemented reporting is the list of Worst Performing Trains (Table 4). In this reporting, trains are sorted after their worst meridian for measuring points. Since neighbouring measuring points also tend to have similar values, the 10 worst measuring points are listed in descending order. Only trains where the meridian for the worst measuring point shows a delay of more than 4 minutes and 59 seconds are included. Since the threshold for Delay Reports also is 4 minutes and 59 seconds, it is thus possible to find the reasons for most delays through the Delay Reports. The typical period of time examined is a month and only trains which have been operating on minimum 50% of the days during the period are included.

Table 4: Worst performing trains.

NR	TRAIN	TYPE	TOP_01	TOP_02	TOP_03	TOP_04	TOP_05	RESPONSIBILITY LAST DELAY REPORT
1	42703	HG	ØRE G: -178,17	KLV G: -177,67	HTÅ I: -166	HIF G: -160	GL G: -160	Ekstern: 16
2	38802	HG	PHM G: -119,33	TRK G: -110,83	HH G: -110,17	CPH G: -110,17	RO G: -110	Ekstern: 12 HECTORRAIL, Hectorrail: 3
3	44735	GD	VK G: -91	PA I: -90	OJ G: -79,33	TE G: -78,83	FZ G: -78,83	Ekstern: 16 RAILION, Railion: 4
4	42738	GD	TRK G: -73,33	RO G: -72,17	HH G: -71,67	BO G: -71,5	VY G: -71,33	Ekstern: 13 RAILION, Railion: 4 BANE, Proj
5	44748	GD	CPH G: -72,5	VM G: -67,83	FZ G: -67,5	LK G: -67	KD G: -66,17	Ekstern: 10 RAILION, Railion: 2 BANE, Sikri
6	44721	GD	TE G: -64,33	OJ G: -64	RQ G: -63,83	SST G: -63	VK I: -62,5	Ekstern: 18 RAILION, Railion: 4 BANE, Proj
7	42737	GD	VK I: -61,83	VKU I: -60,5	OJ G: -60,33	TE G: -60	SST G: -60	Ekstern: 10 BANE, Sikring: 1 RAILION, Raili
8	42735	GD	VK G: -41,5	PA I: -40	TE G: -39,5	KØ G: -39,17	RQ G: -38,5	Ekstern: 11 RAILION, Railion: 4 DSB, Passa
9	44709	GD	RQ G: -35	TE G: -33,67	VK G: -33,5	PA I: -32	SNO G: -30,5	Ekstern: 13 RAILION, Railion: 3 BANE, Fjerr
10	46256	GX	PA I: -30	SO G: -6	RG I: -6	FJ G: -5,5	SG G: -5	Ekstern: 12 RAILION, Railion: 1
11	482	EN	KA G: -27	EB I: -26	MD G: -26	KD I: -25,5	KD U: -24,33	Ekstern: 19 DSB, Drift: 1 RAILION, Railion:
12	44731	GD	PA U: -27	TE I: -19	OJ G: -17,33	RQ G: -16,33	SST G: -16	Ekstern: 9 BANE, Projekt: 6 RAILION, Railic
13	44707	GD	FJ G: -25	SO G: -24,67	RG G: -24	SG G: -23,83	FO G: -23	Ekstern: 15 RAILION, Railion: 2 BANE, Spor
14	44722	GD	PHM G: -20,83	CPH I: -19,67	TÅT G: -18,83	KLV G: -17,83	IG G: -15,17	Ekstern: 12 RAILION, Railion: 5 BANE, Sikri
15	44732	GD	TÅT G: -20,33	KLV G: -20	CPH I: -19,67	IG G: -19	TRK G: -18,83	Ekstern: 9 RAILION, Railion: 4 BANE, Proj
16	9229	G	BO G: -14,67	SO G: -14,33	KY G: -14,33	VY G: -14	RG G: -14	RAILION, Railion: 10 DSB, Ffæst: 2 BANEP, 1
17	33	IE	RF U: -12	RF U: -10	NF I: -8	TRK G: -3,17	NF U: -3	Ekstern: 18 DSB, Ffæst: 1 DSB, Togsæt: 1
18	44718	GD	MY G: -11,5	UV G: -10,83	JU G: -10,33	NG I: -10	OD G: -10	Ekstern: 7 RAILION, Railion: 3 BANE, Proj
19	40008	GK	PA I: -11	RQ G: -2,83	TL I: -2	KD G: -2	VM G: -2	Ekstern: 10
20	38851	GD	VK G: -10,33	OJ G: -10	TE G: -10	RQ G: -9,83	SST G: -9,33	Ekstern: 6 BANE, Projekt: 5 RAILION, Railic
21	44737	GD	TE G: -9,33	VK I: -8,5	VK U: -6,83	PA I: -6	SST G: -5	Ekstern: 5 RAILION, Railion: 5 BANE, Sikri
22	910	IC	KN U: -9,17	KH I: -9	KN I: -8,17	KH U: -8	KK I: -8	DSB, Passenger: 4 Ekstern: 4 BANE, Sikri
23	9424	G	HTÅ I: -8,83	GL I: -6	TRK G: -5,33	RO G: -4	RG U: -4	RAILION, Railion: 10 BANE, Sikring: 2 CFLC
24	60044	M	CPH I: -8,5	TÅT G: -7,5	KLV G: -6,83	KH U: -6		DSB, Togsæt: 4 BANE, Spor: 2 Ekstern: 2
25	7515	G	FA U: -8	BK G: -3,33	BET G: -83	VI I: -17	HR I: 0	RAILION, Railion: 13
26	1516	RØ	KN U: -8	KN U: -7,33	KK I: -7	HGL I: -5,5	KK U: -5,5	DSB, Togsæt: 3 Ekstern: 3 BANE, Sikring: 2
27	381	IE	OJ G: -7,5	TE G: -6,83	VK I: -6,33	SST G: -6,17	RQ G: -5,33	DSB, Passenger: 4 DSB, Togsæt: 4 BANE, Sik
28	2218	RØ	KN U: -7,5	KK I: -6,67	KH I: -6,5	KH U: -6,5	KN I: -6,33	DSB, Lok-Vogne: 4 Ekstern: 4 BANE, Spor: 2

Since the summer of 2009, the reporting of the Worst Performing Trains has been carried out on a monthly basis. The reporting is distributed internally to the timetabling section, amongst management and externally to RUs with the expectation that all parties attempt to locate the root causes for the delays and act accordingly. The list of Worst Performing Train plugs the gap in the Plan – Do – Check – Act circle. Until this reporting was implemented, there was no formal systematic feedback loop in the timetabling process [7].

The initial experience is that in most cases, the list reveals no major surprises. There are in most cases well known explanations for why trains are on the list. These may be that the trains are freight trains (different nature of operation), running during the night and technically delayed by planned system possessions (Rail Net Denmark uses system possessions on the busiest part of the network) or trains arriving late to the Danish Railway Network from abroad.

Even if there are well-known reasons that are difficult to resolve for the trains being on the list, the list of Worst Performing Train quantifies the performance of each train in relation to the other trains as well as in absolute terms. E.g. on one railway line the 2010 timetable works much better than the 2009 timetable in terms of systematic delays. This manifests itself by noticeably fewer trains from that line being on the list in 2010 compared to in 2009.

Even though the list of Worst Performing Trains has been generally accepted, the implementation and use still merits more analysis and actions. Or as the head of the timetabling section concluded: “The list of Worst Performing Trains contains lots of yet unharvested information”.

6.2 Loss of time on open line

The Loss of Time on Open Line method (Figure 3) is also a well implemented reporting. Here different percentiles for loss or gain of time on open line are calculated for a group of trains over a period of time.

Typically the 50%, 70%, 80%, 90% and 95% percentiles are calculated. The 50% percentile in Loss of Time on Open Line reporting is generally either due to local speed restrictions or technical properties of the measuring points (halts) while the 90% percentile is where poorly running trains typically begin to create delay-peaks. Peaks at lower percentiles indicate factors which are common for all trains, e.g. local speed restrictions whereas peaks at higher percentiles indicate factors which can be isolated to one or a few trains e.g. timetable conflicts or train traction power problems.

On top-managerial levels, this reporting has been used to focus the attention on the reason behind delay or as a senior Rail Net Denmark manager once concluded “if the 50% best running trains can keep the schedule, the problem cannot be the infrastructure”. The Loss of Time on Open Line reporting is used ad hoc when in-depth analysis is need of lines.

The overall development in the performance of products on a line can be illustrated calculating the average loss of time between measurement points for the different percentiles over a given period of time (Figure 4). Such an aggregation will only reveal information on a much aggregated level, which allows general trends to emerge.

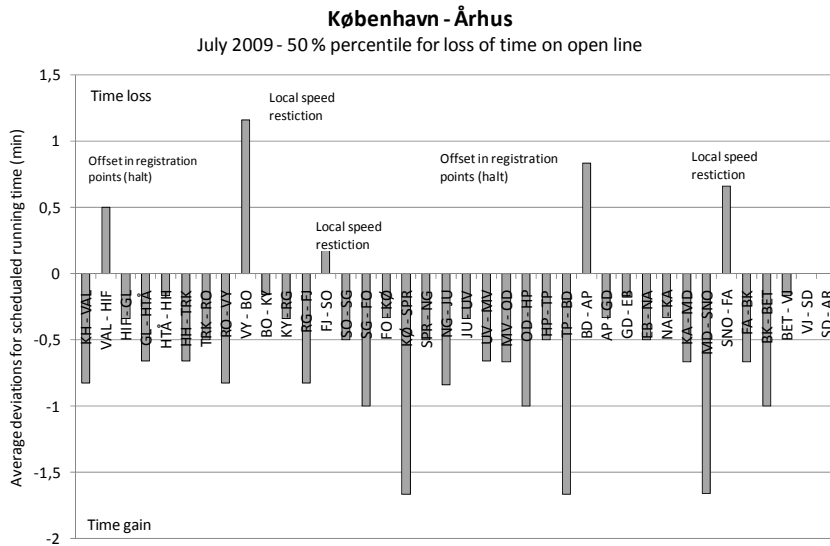


Figure 3: Example of loss of time on open line.

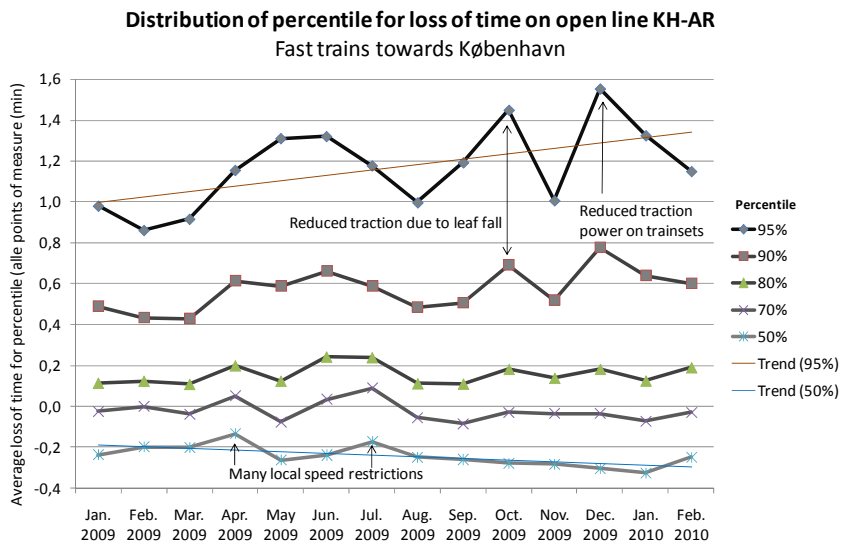


Figure 4: Development in percentile for loss of time on open line.

An aggregated reporting can also be used to evaluate the difference in performance between different train products. The timetable for the rush hour train in Figure 5 is very ambitious which clearly shows.

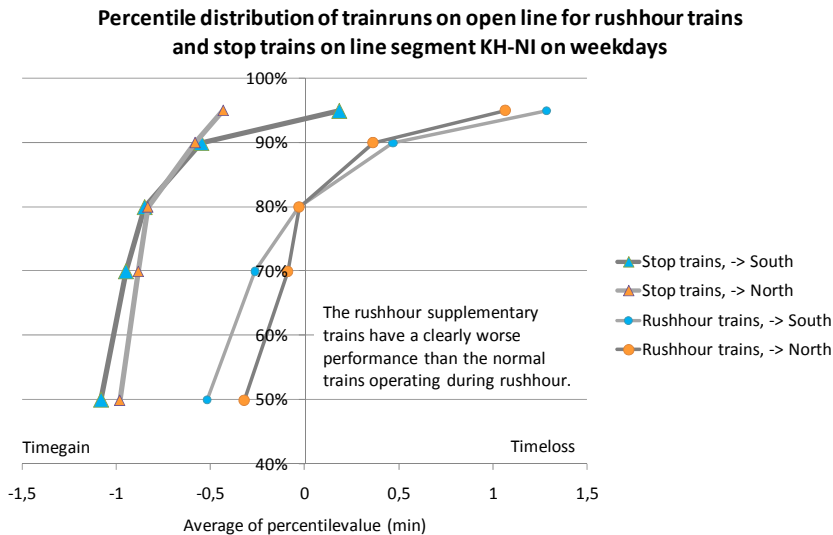


Figure 5: Comparison between train products.

6.3 Realised timetable

The newest reporting is the Realised Timetable reporting. In this reporting, the meridian of the timetable deviation at a number of measure points for trains is plotted for each train as a realised timetable.

Table 5: Realised timetable.

Median for schedual deviation for passage times during March 2010, weekdays.													
Schedule	Station ->		HTA		GL	HIF	VAL		KH		KN	KK	
Dep HTA	Headway	Train	Arrival	Dep	Pass	Pass	Arrival	Dep	Arrival	Dep	Arrival	Dep	Arrival
08:43:00		2512	1,0	-0,7	0,2	0,0	-0,3	-2,0	-2,0	-1,8	-1,8	-2,8	-2,0
08:48:00	5 min	1512	-0,2	-1,0	-0,2	0,3		-1,0	-2,3	-3,0	-3,5	-4,5	-4,8
08:50:00	2 min	4210	-0,2	-0,8	0,0	0,3	0,7	-1,0	-1,7				
08:53:00	3 min	44718	-2,3	-1,0	0,7	1,3							
08:58:00	5 min	8114	-2,5	-4,0	-2,5	-2,3		-2,2	-4,0	-4,0	-4,7	-5,5	-6,0
09:00:00	2 min	4112	-2,2	-2,3	-1,7	-2,0	-1,0	-2,5	-2,7	-0,5	-2,3	-3,3	-2,3
09:06:00	6 min	108	-1,2	-2,3	-1,5	-1,5		-2,0	-3,7	-2,2			
09:10:00	4 min	10	-2,2	-3,5	-2,5	-2,2		-4,0	-3,7				
09:13:00	3 min	4514	-0,7	-2,2	-1,5	-1,5	-1,0	-2,5	-3,2	-1,7	-1,7	-3,0	-2,7
09:17:00	4 min	8214	-2,7	-3,3	-2,7	-3,0	-2,2	-3,8	-3,3	-3,5	-3,0	-4,2	-3,5
09:23:00	6 min	8314		-3,7	-3,8	-4,3		-3,0	-6,8				
09:28:00	5 min	16		-1,7	-0,5	0,2		0,5	-3,0	-3,0			
09:30:00	2 min	4114	-2,7	-3,0	-2,2	-2,7	-1,8	-3,3	-5,2	-3,0	-2,0	-3,0	-3,0
09:35:00	5 min	910	-2,7	-3,7	-3,0	-3,5	-4,7	-6,0	-9,0	-8,0	-8,2	-9,2	-8,0
09:43:00	8 min	2516	1,2	-1,0	-0,3	-0,2	0,2	-1,5	-4,2	-3,5	-3,3	-4,0	-3,2
09:48:00	5 min	1516	-0,3	-1,5	-0,5	-0,3		-2,0	-5,2	-5,0	-7,3	-8,0	-7,0
09:58:00	10 min	1218	0,0	-1,0	0,0	-0,2		-1,0	-4,0	-3,2	-3,0	-4,0	-3,7
10:00:00	2 min	4116	-0,8	-2,0	-0,7	-1,0	-0,2	-1,8	-2,3	-0,2	-1,3	-2,2	-1,2
10:06:00	6 min	114	-1,2	-2,3	-1,3	-3,2		-3,2	-6,2	-3,7			
10:10:00	4 min	14	0,0	-1,0	0,2	0,5		-3,0	-6,5				
10:13:00	3 min	4518	-1,5	-2,5	-2,0	-1,7	-1,2	-2,8	-3,0	-3,7	-3,2	-3,8	-2,8
10:17:00	4 min	2218	-3,7	-4,3	-3,3	-4,0	-3,0	-4,3	-4,0	-4,5	-6,0	-7,0	-6,5
10:30:00	13 min	4018	0,2	-0,7	0,3	0,2	1,0	-0,5	-0,8	1,8	1,0	0,3	0,8
10:35:00	5 min	812	-0,2	-1,3	-0,7	-1,5	-0,8	-2,5	-3,7	-3,0	-1,7	-2,7	-1,5



This reporting is used to do an in depth analysis of a network section. The aim is to illustrate which trains often run late and whether this causes consecutive delays to other trains. E.g. in Table 5, train 8114 leaves HTÅ with a delay of 5 minutes or more during more than half the days, which causes consecutive delays for the next 6 trains. Train 2218 seems also to be performing poorly, but since there are no trains scheduled to run just after this, this trains does not cause consecutive delays to other trains. An in-depth analysis of the neighbouring network sections is to be carried out to determine where in the network the delays of train 8114 originate.

This reporting is currently being used to analyse the traffic around Copenhagen where there are problems with consecutive delays due to dense traffic.

6.4 Perspective and results obtained

The percentile approach has been used for around a year and has yielded new information in new reportings. The reportings presented in this paper are the most successful in Rail Net Denmark to date but more will be developed depending on the demands.

Fundamentally, four different methods can be used when aggregating the data

- **Isolating the trains or groups of trains**

The list of Worst Performing Trains is an example of this (Table 4).

- **Isolating the geography**

The Loss of Time on Open Line is an example of this (Figure 3).

- **Isolating the time period**

- **Isolating the percentile**

The methods may be combined depending on the requirement. The realised timetable (Table 5) and the two distributions of percentiles (Figures 4 and 5) are examples of combinations of these different aggregations.

An issue to be investigated is at what percentile, the poorly performing trains begin to emerge, how constant this value is and what information can be deducted from these analysis. Presently, it appears that this happens around the 90% percentile. Examination of the distribution of delays versus percentiles should also be carried out to yield information on what is “best practice” and what can be considered as poor performances. An academic vision is to develop a timetable quality measure describing the trains’ ability to stay punctual and the ability to recover after disruptions.

7 Organisational implementation

Though successful, the percentile approach cannot replace the present affected train KPIs, and should not be considered as a replacement either. The approach is orthogonal yielding new additional information. The approach is not an advanced theoretical statistics approach either but a hands-on approach born out of requirements from an operations environment.

The development and implementation process can be described as a push-pull approach. Pull because there has been a general company-wide requirement for more information describing performance shortfalls and push because no-one had previously requested reportings based on a percentile approach.

The success experienced with the percentile approach is due to more advanced analysis being able to deliver answers to questions already posed in the organisation. The success is also due to the top management being very data- and KPI oriented and thus promoting a corporate mindset welcoming more advanced reportings.

8 Conclusion

Analysing all timetable deviations with a percentile approach and not only those above a predefined threshold yields valuable new information. The delay percentiles can be aggregated on train numbers (or groups of trains), geography (measuring points), time period, percentile or as a combination. A number of reportings have been developed helping Rail Net Denmark locate systematic causes for delays. These can be used to achieve a better punctuality.

The percentile approach is orthogonal to the classical analysis of cause of delay above a threshold and should not be regarded as a substitute but as a valuable supplement.

The organisational implementation and acceptance is essential. The success of the percentile approach is amongst others an emerging need for more advanced analysis as well as a general shift in the corporate mindset towards a higher KPI focus.

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