Differences in signals passed at danger – looking for patterns[1]

Veel methoden voor het beschrijven van incidenten en ongevallen maken gebruik van rubriceringen. Daaruit wordt niet direct duidelijk wat nu de echte oorzaken zijn. Redenen daarvoor zijn onder andere dat omstandigheden en toedracht vaak ter plekke worden vastgesteld als heel feitelijke constateringen, en dat er vaak sprake is van een samenloop van omstandigheden. Dit artikel laat zien hoe een opmerkelijk verschil in incidenten tussen passagierstreinen en goederentreinen niet opvraagbaar bleek uit de database of niet tot significante verschillen leidde. Via een procesanalyse kon de grote diversiteit in de gegevens in verband worden gebracht.

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Signals passed at danger (SPADs) constitute a major rail safety problem. The Dutch train protection system ATB-EG, which is by far the widest spread in Holland, allows trains to pass signals at danger with speeds up to 40 kmh without system brake intervention. In The Netherlands during the period 2002-2006 1 fatality and 194 people injured were recorded as a result of SPADs. In most cases SPADs lead to delays and/or damage to the rail infrastructure (Dutch Rail Inspectorate, 2007), thus having an economic impact as well. According to statistics from the Dutch Rail Inspectorate (DRI) the number of SPADs in 2006 increased by 8 percent compared to the reference year 2003. Because a national target of a decrease in number of SPADs of 50 percent by 2009 was formulated this development causes major concerns.

In its yearly analysis of SPADs over the last five years the DRI (2007) concluded that cargo trains[2] are significantly more often (a factor 2.6) involved in SPADs than passenger trains (table 1).

Table 1. SPADs in the period 2002-2006

	Number of SPADs	Train kilometres	#SPADs/mio km
Cargo trains	195	47.682.235	4.09
Passenger trains	950	608.437.070	1.56
Total	1145	656.119.305	1.75

[1] Dit artikel is een bewerking van een artikel gepresenteerd op de '3rd International Conference on Rail Human Factors' in Lille, maart 2009: '(Why) are Dutch cargo trains 2.6 times more often involved in SPADs compared to passenger trains?'
2 'Trains' should be read as any rolling stock (locomotives, wagons, train units, composite trains).

As it may be argued that cargo trains are more vulnerable to SPADs due to the many shunting movements, 38 distinct SPADs on marshalling yards were identified and excluded. The number of cargo SPADs on the shared infrastructure then decreases to 157 and 3.29 per mio km, which is still over a factor 2 more than passenger trains. As there were no significant differences between cargo train carriers an investigation on behalf of the entire Dutch rail cargo branch was commissioned.

We were asked to identify assignable causes of the difference in SPADS per million train kilometres in the period 2002-2006 between cargo and passenger transport, and to formulate measures to influence these causes (if any). This paper is based on a research report (Van der Weide et al, 2008).

Method

We chose to use the DRI's SPAD database (par. 2.1) as a basis for our statistical analyses. To formulate hypotheses to test using the database our approach is characterised by process and task analyses (par. 2.2). Thus, we assumed that by identifying differences in processes and tasks/means between cargo and passenger rail transport we could identify causes and contributing factors to the differences in number of SPADs.

SPAD database

DRI's SPAD database contains 1145 relevant (non-technical) SPADs for cargo and passenger trains over the years 2002-2006 (Table 1). As mentioned before 38 of the 195 cargo SPADs were distinct cargo shunting situations. These were treated as a separate group, and were not included in the statistical comparison between cargo and passenger SPADs. Thus, this comparison was made on 157 cargo and 950 passenger SPADs, a grand total of 1107 SPADs.

The SPAD database contains general data about day/time and location of the SPAD, signal type and number, carrier, driver, etc. It also contains data about primary causes (10 categories) and secondary causes, which are merely subcategories of the primary causes, and about the effects of the SPAD (10 categories) and the 'seriousness' of the SPAD (9 categories) (for descriptions, see DRI, 2007). Furthermore, contextual data of e.g. delays, deviation of plan/routes, work on or along the tracks, hour of service, experience on the job, route knowledge, frequency of passing the signal, etc. is recorded. The database is filled by selected DRI personnel on the basis of standard forms, that are mandatory filled in by the driver, the driver's management/safety executive and the train dispatcher. However, these forms did undergo some development over the years, and not every carrier changed to a newer version at the same time.
To get an impression of the data quality in the database compared to the entire files containing all forms, we randomly studied 13 files of one cargo carrier. We concluded that in all cases DRI had distilled data correctly from the files.

Process and task analyses

Through interviews and a workshop with representatives from all cargo carriers, the largest passenger carrier and traffic control we drew up process and driver task analyses focussing on differences between cargo and passenger transport. This is to lead to hypotheses that can be statistically tested using the SPAD database.

Statistical analyses

The Chi-square test is used to establish whether the distribution of the frequency of SPADs between cargo and passenger transport deviates from the expected distribution. A $p \leq 0.05$ is considered statistically significant.

Results

Process and task analyses

The main differences in processes and tasks between cargo and passenger transport are (full analyses in Van der Weide, 2008):

- Cargo processes are less predictable, possibly leading to more time pressure, to more and complex communication, to more unexpected/unplanned routes and red signals, to a greater appeal to route knowledge, and to more frequent passing of dwarf signals.
- Cargo trains are heavier and vary more in brake characteristics, leading to longer braking distances and needing considerable braking skills.
- Cargo locomotives are on average ergonomically less sound (e.g. lines of sight, climate).
- Cargo rosters are less favourable with more night shifts, possibly leading to more fatigue and errors (RSSB, 2005).

Primary and secondary causes

Table 2 shows the involvement of primary causes in SPADs, both in number of SPADs per million train kilometres and in percentage of the total number of SPADs per transport mode. Both are meaningful: the former to indicate the absolute involvement, the latter to show differences in distribution between modes. For other aspects we focus on this relative difference.

Furthermore it appears that brake actuation is significantly more often the *sole* primary cause in cargo SPADs compared to passenger SPADs (12% vs. 6%). Also, the number of SPADs with an unknown (unregistered) cause differs significantly between cargo and passenger transport: 11% vs. 6%.
As statistical significant secondary causes the following come up (Cargo vs. Passenger as % of primary cause):

- brake actuation: incorrect brake actuation (8% vs. 3%);
- board procedure: incompliance with rules (97% vs 43%).

[3] For definitions see DRI (2007).

Table 2. Top 6 primary causes (> 10 cargo SPADs in the period 2002-2006)

Primary cause[3]	Cargo (C)		Passenger (P)	
	#SPADs/mio km	% of total C	#SPADs/mio km	% of total P
Brake actuation	2.33*	79.3%	1.24	84.5%
Perception	1.55*	52.9%*	1.05	71.5%
Board procedure	0.65*	22.1%*	0.21	14.3%
Distraction	0.61	20.7%*	0.47	32.2%
Expectation	0.46	15.7%*	0.39	26.5%
Technical circumstances	0.36	12.1%	0.23	15.9%

*** $p \leq 0.05$. Note that multiple primary causes may be present at one SPAD.**

Contextual characteristics

Based on the process and task analyses table 3 contains contextual data.

Note that no data is available about the number of cargo and passenger train kilometres per time category, and the number of works and other deviating situations cargo and passenger trains encounter. As the cargo process has a substantial nightly component (50% are nightly shifts), and a lot of track work takes place at night, this may be related to the number of SPADs in these hours. The greater percentage of SPADs for cargo trains not riding on time may be related to the lower punctuality of cargo trains: arrival punctuality (≤ 3 min. delay) for cargo trains is about 65% whereas passenger trains reach 85% (ProRail, 2006). In about 50% of all SPADs one or more deviating situations are present.

Table 3. Contextual SPAD data as % of total Cargo and Passenger SPADs respectively in 2006[4] (* $p \leq 0.05$)

Time of day	Cargo	Passenger
00-06 h (night)	19.5%	13.4%
06-07 h (morning, before rush)	0%	3.4%
07-10 h (morning rush hours)	17.1%	21.2%
10-16 h (day, no rush)	24.4%	34.1%
16-19 h (evening rush hours)	17.1%	15.1%
19-24 h (evening, after rush)	22.0%	12.8%
Train on time	**Cargo**	**Passenger**
Yes	36.6%	60.3%
No	26.8%*	12.8%
Unknown	22.0%	20.1%
Not applicable	14.6%	6.7%
Works on/along the track	**Cargo**	**Passenger**
Yes	14.6%	3.9%
No	65.9%	76.0%
Unknown	19.5%	20.1%
≥ 1 Deviating situation[5]	**Cargo**	**Passenger**
Yes	61.0%	46.4%
No	22.0%	38.5%
Unknown	17.1%	15.1%

Driver characteristics

Table 4 shows driver related characteristics. Here it must be noted that not all carriers gave insight into their distributions of age categories. From the largest cargo carriers we know that there are hardly any drivers in the youngest category. In the category 50-59 year cargo drivers are less often involved in SPADs; this age group is certainly not small.
Driver's experience shows remarkable differences between cargo and passenger transport. Distribution of experience groups within cargo and passenger driver populations is unknown. It appears that cargo drivers with 3-10 years of experience are more often involved in SPADs, while the groups with the smallest and largest experience are less

Table 4. Driver's age and experience when involved in SPADs (2002-2006)

Age (year)	Cargo	Passenger
20-29	5.7%	3.1%
30-39	14.6%	15.9%
40-49	21.7%	27.7%
50-59	4.5%*	21.8%
60-64	0.6%	0.9%
Unknown	52.9%*	30.6%
Experience on the job (year)	**Cargo**	**Passenger**
0-2	8.3%*	16.4%
3-5	14.6%*	9.2%
6-10	12.7%*	7.8%
11-20	11.5%	17.6%
>20	9.6%*	24.5%
Unknown	43.3%*	24.5%

*** $p \leq 0.05$**

4 Data from 2006 (not from 2002-2006) because part of these data is only collected since 2006.
5 Deviating situations are: train not on time, intersecting routes, partial routes, manually set routes, changed plan, deviating routes, deviating time-table, works in progress.

often involved compared to passenger drivers. Striking is the large amount of unknown (unregistered by carrier) ages and years of experience, especially in the cargo group. This also was a major problem when analysing the hour of duty: up to 78% of the data was missing. Other aspects of rosters are not registered at all, thus making conclusions about the impact of rosters and fatigue (RSSB, 2005) impossible.

Clusters

As a next step in the analysis we divided the transport process into sequential clusters: leaving the marshalling yard and entering the shared infrastructure (via a signal or stop board), the open track (with automatic signals), entering a station yard (via an entry signal), arrival at/departure from the platform or other movements on the yard, leaving the station yard (via an exit signal) onto the open track again, and entering/leaving track off service. For every cluster we analysed braking situation (driving, shooting or sliding through, rolling), type of signal (high, dwarf, stop board), primary and secondary cause (see 3.2) and rolling stock type (cargo/passenger train, single locomotive or wagon, shunting part, empty rolling stock). We separately analysed the 38 distinct cargo shunting SPADs. Figure 1 shows the overall results (details in Van der Weide, 2008).

Nearly all cargo SPADs on the shared infrastructure take place during 'other' movements at 'other' yard signals. In 80% of these cases they are *not* coded as departure related, so it may be assumed that trains are moving when confronted with a red signal. The braking situation then becomes very important. It appears that *driving* through a red signal happens at dwarf signals and stop boards (far less at high signals) with primary causes Perception/Brake actuation and Board procedure (no permit from dispatcher) respectively. *Shooting* through a red signal happens at both high and dwarf signals with primary causes Brake actuation and/or Expectation/Distraction. *Rolling* through a red signal is primarily caused by incorrect stabling (parking) of single wagons or locomotives.

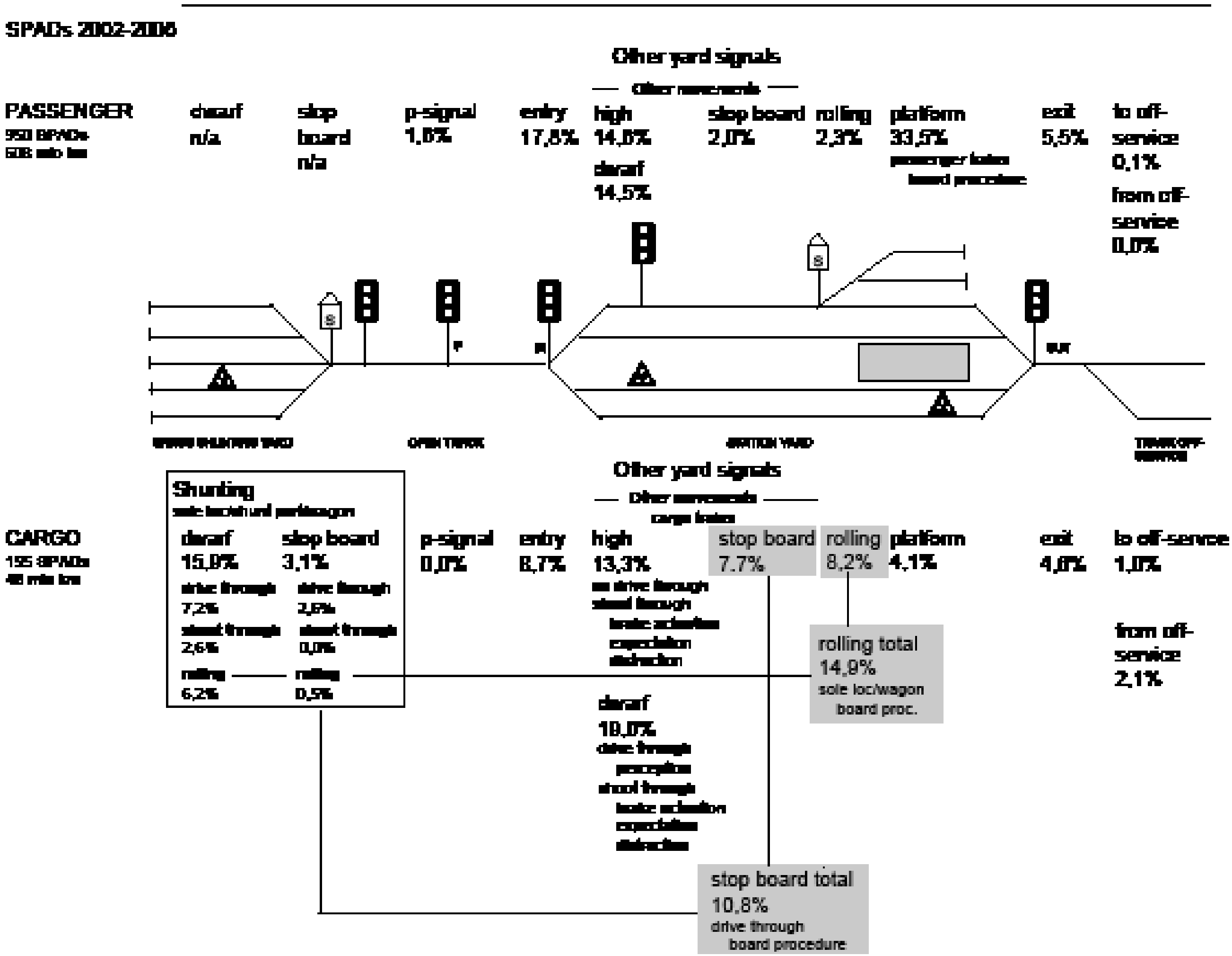

Figure 1. Largest SPAD clusters (in % of total of cargo and passenger transport SPADs, including cargo shunting). Gray shade: significantly more than expected

SPADs in a departure situation at 'other' yard signals are mostly caused by single cargo locomotives or empty passenger trains. NS studied the latter and concluded that inadequate route knowledge is a contributory factor (NS, 2008). Departure from a platform causes relatively many SPADs for passenger trains. An incorrect order of departure by the conductor is an important factor in these situations.

SPADs during shunting on cargo marshalling yards are mainly characterised by single locomotives or wagons and incorrect/inadequate work according to procedures, e.g. incorrect stabling, passing stop boards without permit, or inadequate inspections/checks.

Discussion

Exposure

It was our assignment to try to explain the 2.6x more SPADs per million train kilometres with cargo transport compared to passenger transport. By excluding distinct cargo shunting SPADs (different infrastructure, low mileage) the factor was reduced to 2.1. It was assumed in our assignment that exposure to train kilometres would allow a fair comparison. In other words, is the exposure to red signals per train kilometre the same for cargo and passenger transport? We tried in several ways to quantify this exposure but were unsuccessful within project time and budget constraints. However, as a result of our process analyses and associated interviews and workshops it became clear that the less predictable cargo process leads to relatively many changes of plan and route. Dispatchers declared that they relatively often 'have to take cargo trains aside', which means that they lead cargo trains that do not arrive according to plan onto the yard to let other trains pass. The plan itself does not take cargo process characteristics adequately into account. It is merely based on standard hourly timetables. Cargo train are thus encountering more (unplanned) red signals, and a greater appeal to the driver's route knowledge is being done.

At a more detailed level the same holds for the analysis in clusters (figure 1). We don't know the exposure to the different signal locations for both transport modes. Obviously, passenger trains halt at platforms more frequent than cargo trains do, just as cargo trains are led across the yard more often than passenger trains. It thus seems logical that passenger trains are more frequently involved in SPADs along the platform and cargo trains in SPADs on the yard. This implies an impossibility to quantitatively explain the difference in SPADs per kilometre.

Braking

It is made clear from the results that braking in cargo trains is a critical factor. As cargo trains are heavier and have different brake characteristics depending on the load, rolling stock, etc. a greater appeal on braking skills is done. From the interviews it appeared that there is no extra attention to these skills in the cargo driver's basic training. Of course, during practical training the driver learns under supervision, but the amount and circumstances are limited.

Experience on the job

Although reference figures about experience were not obtained, it seems that cargo drivers with 3-10 years of experience are overrepresented in SPADs. As rail regulations state that drivers during their first two years are limited to a certain area and associated rolling stock and velocities, it may well be that they are inadequately prepared for the larger area (route knowledge), rolling stock and velocities (brake characteristics). Cargo carriers recognised this during a final workshop.

Conclusions

- Train kilometres do not constitute an adequate measure for exposure to (unplanned) red signals. It is plausible that this exposure is higher for cargo transport, although exact figures are not available.
- Brake actuation is as sole primary cause or in combination with Perception, Distraction, Expectation or Board procedure an important factor in cargo SPADs. This may well be related to heavier trains and different brake characteristics of cargo trains, a greater appeal to route knowledge, and inadequate training.
- Four clusters (par. 3.4) can be identified with relatively many and specific cargo SPADs: 'other' yard movements, shunting, rolling and passing of stop boards.
- Cargo carriers are less compliant in delivering (compulsory) SPAD data.
- Cargo drivers with 3-10 yrs experience seem overrepresented in SPADs.

We advised to proceed with the implementation of advanced train control systems (ERTMS, ATBvv) to prevent SPADs at all or minimize their risk. Improved timetables that justify the cargo process and systems that give the driver insight in future situations are mitigating risk measures. If a true comparison is to be made between cargo and passenger transport then an exposure measure to (unplanned) red signals has to be developed. Route knowledge and visibility/conspicuity of signals need to be further studied. Compliance to SPAD related procedures – by the driver, carrier, dispatcher, and inspectorate – need to be improved. And finally, training and instruction on braking skills are to be analysed and improved when necessary.

Epiloog

In het artikel wordt het punt gemaakt dat het aantal roodseinpassages per treinkilometer geen goede basis is voor een vergelijking tussen reizigerstreinen en goederentreinen. Een goede vergelijking van het risico is alleen mogelijk als de blootstellingsmaat de juiste is. In dit geval zou de blootstelling aan gele ('snelheid begrenzen tot maximaal 40 km/u en rekenen op een volgend rood sein') en rode seinen ('stop vóór het sein') een betere maat zijn dan treinkilometers. Immers, vanuit de formule Risico = Kans x Effect en Kans = Blootstelling x Waarschijnlijkheid is Waarschijnlijkheid de interessante factor met betrekking tot menselijke (on)betrouwbaarheid. De Kans op roodseinpassages is bekend uit de STS-database; als we er dus in slagen om de Blootstelling op een juiste wijze te kwantificeren dan weten we dus vanzelf meer over Waarschijnlijkheid. Ten tijde van ons onderzoek was de blootstelling aan gele en rode seinen echter onbekend. Inmiddels weten we dat in 2008 ruim 8 miljoen treinen met een rood sein geconfronteerd werden; 240 daarvan zijn door het rode sein gereden. Dat is een kans van 1:34.000. Zo'n 80 procent betreft menselijke fouten, hetgeen overeenkomt met een kans van 1:42.500 (0,00002) (de Raadt, 2010). Helaas is op dit moment het onderscheid tussen reizigerstreinen en goederentreinen nog niet gemaakt.

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Samenvatting

Afgaande op de cijfers van Inspectie Verkeer en Waterstaat (IVW) over de jaren 2002-2006 zijn goederentreinen 2,6 maal zo vaak betrokken bij Stop Tonend Sein passages (STS) per miljoen kilometers als passagierstreinen. Intergo kreeg de opdracht de oorzaken van de verschillen te onderzoeken en maatregelen te formuleren.
De basis voor onze aanpak vormde een proces- en taakanalyse voor goederen- en passagiersmachinisten. Deze analyses lieten verschillen zien in processen en taken die leidden tot hypothesen om de verschillen in STS te verklaren. De hypothesen werden statistisch getoetst met de IVW database. We analyseerden verschillen in primaire en secundaire oorzaken, en combinaties hiervan, en combineerden deze met subprocessen en taken. Dit leidde tot grote typische STS-clusters van 'rangeerbewegingen op emplacementen', 'bewegingen binnen een station', het passeren van 'dwergseinen' en 'stopborden' en het '(door) rollen van treinen'. Verschillen in machinistkenmerken en conformiteit van vervoerders speelden een rol. Ook verschillen in blootstelling aan het gevaar en de referentiemaat worden besproken.

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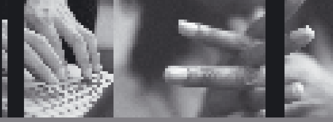

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