IMPROVING SAFETY OF SHUNTING MOVEMENTS

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ABSTRACT

Collisions against parked vehicles are regularly related to shunting routes that are formally permitted but unexpected are regularly involved in practice. Drivers or shunters bear only part of the responsibility, as signaller's mistakes and inaccurate track side signalling are often contributing causes. Such collisions cause normally no fatalities. They induce nevertheless high costs in rolling stock and infrastructure repairing and can reduce significantly the capacity, or even the availability, of a station, especially when main lines are impacted.
After defining the case of permitted but unexpected shunting routes, some shunting collisions against parked vehicles are discussed, keeping in mind the confidence and the supervision principle. Then, a list of proposals on both procedures and equipment is presented. Among them, the use of the digital radio GSM-R is specially highlighted. GSM-R, connected with local interlocking, makes it possible to display on the DMI the tracks circuits on the permitted shunting route that are occupied. Without using GSM-R, blinking of shunting signals to make aware of an occupied track section is probably a fair improvement in shunting moves safety for Switzerland.

INTRODUCTION

Shunting moves exist from the early days of railways. As traffic increases, more and more regulations and safety devices have been developed by railway companies. According to the philosophy and calculation of risk of each company or country, railway stations and lines have been equipped with different safety devices. Nowadays, everyone in Europe has the Technical Specifications for Interoperability in mind. Primarily developed to increase interoperability, they also foster the European Train Control System, a common safety platform. Unfortunately, the safety of shunting moves is out of scope of this big unifying initiative. However, the use of the secure digital radio GSM-R could increase the safety.

When train movements and shunting movements could frequently be in conflict, protection of both movement types have to be guarantee with fixed signals. This should also be the case in large shunting areas where many shunting moves could happen at the same moment.
Even with correct interlocking and signalling installations, collisions may still occur.

The purpose of the study is to understand why collisions of shunting moves happen on permitted but unexpected routes, and to propose improvements. The first section explains why some permitted shunting routes can be qualify of unexpected routes in Europe. The second section discusses the confidence and supervision principle during shunting moves. The third section analyses some collisions with an obstacle on permitted but unexpected routes in Switzerland. The fourth section focuses on possible measures to improve overall safety and leads to the concluding section.

SIGNALS AND SPEED LIMITS FOR SHUNTING MOVES

A simple comparison with four main European networks (DE-Germany, FR-France, IT-Italy and UK-Great Britain) shows firstly that dwarf signals with a "2-blank lamps diagonally disposed" aspect or "1-blank lamp" aspect are commonly used to indicate to proceed carefully, as shown in Table 1. No one of the five compared country regulations operates a distinction between entering carefully a free section or entering carefully an occupied section.

Table 1: Signalling [1]-[5][1]

Proceed... Country	CH	DE	FR	IT	UK
...on free section until a specific location	2b_vert.	2b_diag. + vocal			
...carefully on a free section	2b_diag.	2b_diag.	1b	1b or 2b_vert.	2b-diag.
...on an occupied section					
...on a short section			1b_blinking		
...on a siding track					1y+1b or 2y-hor.

b=blank light, y=yellow light, vert.=vertically, hor.=horizontally, diag.=diagonally
vocal = oral announcement with indication of the specific location

Thus, the risk of collision with parked vehicles on an unexpected but permitted route is an issue for all countries.

The maximal speed of 30 km/h for shunting moves on points is common to many European countries, as shown in Table 2. It is therefore not surprising than the default value for the maximal speed of shunting moves supervised by ETCS was set at 30 km/h [6].

Until 2006, the maximal speed on points was 40 km/h in Switzerland, despite the fact that no formal confirmation of running on a free route was given, unlike the German requirement.
Thus, the risk of collision with parked vehicles on an unexpected but permitted route has to deal with an initial speed of 30 km/h.

In Switzerland, it is common that signallers set alternatives routes without informing train drivers. In fact, drivers are informed mainly through signalling: detailed information is directly

[1] *numbers in bracket [...] relate to references*

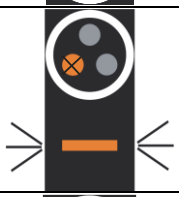
given by signals. Supervision of signallers' actions and train movements are normally fully assumed by high reliable interlocking and automatic train protection systems.

Table 2: Maximal speed allowed for shunting moves [1]-[5]

Proceed... Country	CH	DE	FR	IT	UK
...on free section until a specific location	*40 km/h*[2]	40 km/h			
...carefully on a free section	30 km/h	25 km/h	30 km/h	30 km/h	n.a.
...on an occupied section					
...on a short section					
...on a siding track					5 mph (8 km/h)

For shunting moves, the information is given by less accurate signalling, as shown in Table 3 but signaller supervision is loose and automatic shunting protection systems are rather inexistent.

Table 3: Swiss Caution Signal Types for trains and shunting moves [1.1]

Signal for trains (**not** an exhaustive list)	Information for trains	Information for shunting	Dwarf signal aspect for shunting
	**Stop**		
	**Clear** Next signal shows a Proceed aspect		
	**Caution** Next signal shows proceed at 40 km/h or Caution	**Proceed carefully** Next signal shows Caution, or Next signal shows Stop, or No more dwarf signal. ***Obstacle could stand just after the signal***	 ***aspect #233***
	**Caution** Next signal shows Stop		
	**Caution** Next signal shows Stop ***Short section ahead***		
	**Caution** Next signal shows Stop ***Occupied section ahead***		

[2] *only if not in switch area nor if neighbouring tracks are occupied*

CONFIDENCE'S PRINCIPLE AND SUPERVISION'S PRINCIPLE

Points are necessary but especially dangerous for shunting moves. In fact, if a shunting move passes a facing point in a wrong direction, it is led to a track that was not foreseen, increasing thus the risk of a collision.

> The confidence principle:
> "I presumed that partners act accordingly with rules and what was decided"

In order to act accordingly with what was decided, I must firstly know what was exactly decided. It is therefore quite important that the chief of the shunting moves informs clearly all the partners involved in the process.

> "The chief of shunting determines the sequence of movements, informs all participants about operations having to be carried out, and assigns them tasks." (Switzerland-[1.2])
>
> "Before starting shunting, the chief of shunting must give precise information to concerned staff: shunter, signaller, driver... about what is going to be made" (France-[3.2])
>
> "Before starting any shunting, you must reach a clear understanding with each other about what exactly needs to be done, and how the shunting movements will be controlled" (UK-[5.3])

After this compulsory preliminary step, no one can change the process on its own. Only the time of the beginning of each successive step may vary according to local circumstances.
This preliminary step is very important for the safety of the whole process, as each partner has a joint responsibility to stop or to ask to stop the process, not only if a sudden danger arises, but also if the process diverges from what was planned.

> The supervision principle:
> "Each partner should intervene in the direction of more safety, namely if the process differs from what was decided"

The supervision principle is applicable only with a comprehensive understanding of what has to be done.

> "The objective of the information is to set reference marks for all participants, in order for them to be able to check during execution that the sequence of events is identical to what was planned" (France-[3.2])

It is also obvious that, if each partner thinks that the information is clear, complete and shared among all partners, they become less aware of their supervision responsibility.
This is why it is quite important that the supervision be frequently revived. During the full process, complete information should be shared regularly between partners. The emitter of the information has therefore an opportunity to self-check and receivers can easily compare

the information received with what has been planed in one hand, and with their current perception of the process on the other hand.

ANALYSE OF SOME SHUNTING COLLISIONS WITH AN OBSTACLE ON A PERMITTED BUT UNEXPECTED ROUTE [7],[8]

During years 2004-2007, some collisions of shunting moves against parked vehicles were investigated in Switzerland, as most of them produced high damages *(cf. Tab. 4 and Tab. A1 in annex I)*.

Table 4: Collisions investigated by UUS these last 5 years involving shunting moves (causes, speeds,...)

No	*Date*	*Place*	*Route observance*	*Cause*	*Collision against...*	*Vinitial [km/h]*	*Vimpact [km/h]*
D5	*08.01.2007*	*ZH Herden*	*shunter*	***233***	*parked vehicle*	*= Vimp*[3]	*20*
D4	*15.11.2005*	*Thun*	*driver*	***233***	*parked vehicle*	*38*[4]	*25*
D3	*22.06.2005*	*Palézieux*	*driver*	***233***	*parked vehicle*	*40*[5]	*38*
D2	*29.05.2004*	*Biel*	*driver*	***233***	*parked vehicle*	*33*[5]	*22*
D1	*03.02.2004*	*Zürich*	*driver*	***233***	*parked vehicle*	*40*[5]	*25*
S4	*11.02.2007*	*Zürich*	*driver*	*SPAD*	*shunting move (at points)*	*26*	*10*
S3	*28.04.2006*	*Thun*	*driver*	*SPAD*	*train move (at points)*	*29*	*14*
S2	*07.12.2005*	*Lausanne*	*shunter*	*SPAD*	*parked vehicle*	*= Vimp*[4]	*20*
S1	*20.04.2005*	*Hüntwangen*	*shunter*	*SPAD*	*shunting move (at points)*	*= Vimp*[4]	*11*
I2	*13.05.2008*	*Bern*	*shunter*	*inattention*	*parked vehicle*	*= Vimp*[4]	*26*
B2	*15.06.2006*	*Zürich*	*driver*	*brake contin.*	*buffer stop*	*n.a.*	*5*
B1	*27.04.2004*	*Zürich- RBL*	*driver*	*brake contin.*	*buffer stop*	*n.a.*	*19*
R2	*02.08.2007*	*Arosa*	*shunter*	*radio*	*parked vehicle*	*= Vimp*[4]	*18*
R1	*31.03.2004*	*Zürich*	*shunter*	*radio*	*parked vehicle*	*24*	*20*

*Cause **233** means unexpected but permitted route according to shunting signal aspect #233*

Table 5 focuses on collisions of shunting moves against parked vehicle due to wrong route setting.

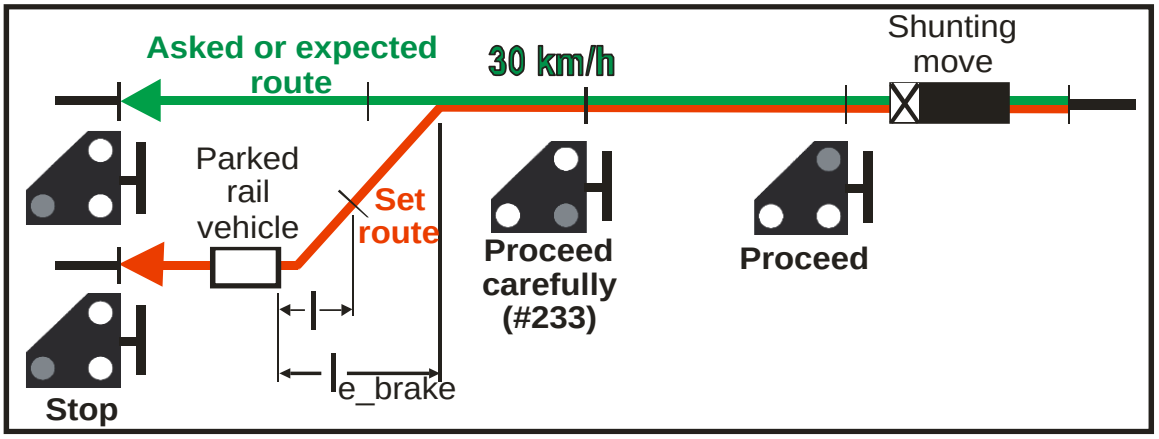
Table 5: Collisions of shunting moves against parked vehicle due to wrong route setting[5]
(a:asked route, e:expected route ↔: change of direction change)

No	Place	route asked(a) or expected(e)	route set up	composition colliding
D5	ZH Herden	423→103↔**809 (a)**	423→103↔**808**	5 wag. + 1 loc.
D4	Thun	216→144↔(5)→**233 (e)**	216→144↔(5)→**235**	1 loc.
D3	Palézieux	5→**12**↔4 **(a)**	5→**17**	2 loc. + 2 wag.
D2	Biel	81→**3 (e)**	81→**2**	EMU (100m)
D1	Zürich	17→J44↔**(J4)→"Heiri"**↔J3 **(e)**	17→**J44**↔J3	EMU (100m)

[3] *no braking action*
[4] *at these times, 40 km/h were allowed if the driver was responsible for the route observance*
[5] *conversations using the shunting radio were not recorded*

Five of these fourteen collisions were due to wrong or unexpected route setting with rather no chance for the driver or the shunter to detect the change in advance *(cf. Fig. 1)*. The main direct reason of the collision was due to the broad range of interpretation of the signal aspect #233[6]. We can also suspect at least two additional reasons why, in four of the five collisions in this category, the shunting move was a pulling movement under the responsibility of the driver: one reason is the high speed of entrance on the occupied track (higher than 30 km/h, what was allowed at these times in these situations), and an other reason is the habits of the drivers to obey signals giving them detailed information about the state of the track ahead *(cf. Tab. 3)*. The lack of point position signal was certainly an aggravating factor.

Figure 1: No information about the point position and numerous interpretations of signal aspect #233



In the reports concerning these collisions, one can read such German words as "glaubte", "in der Regel", "in der Meinung", which are typical to reflect a lack of clear communication between the signaller and the driver/shunter. A free translation of such sentences is given in Table 6.

Table 6 Lack of clear information

No	Place	Comments of the driver/shunter responsible for the shunting move
D4	Thun-2005	"**Normally**, we use track #233 for such movements"
D2	Biel-2004	"**In the opinion** of the driver the shunting move will end on the track #3 what was free"
D1	Zürich-2004	"He **thought** he will run through track J4, as it appeared to be free"

A broad analysis of more than 2'000 accidents, incidents and near misses involving shunting moves on the SBB network the last 5 years shows that only a part of wrong route setting cases leads to a significant damage collision with parked vehicles [8]. In fact, two conditions have to be met to cause an accident with high damages:

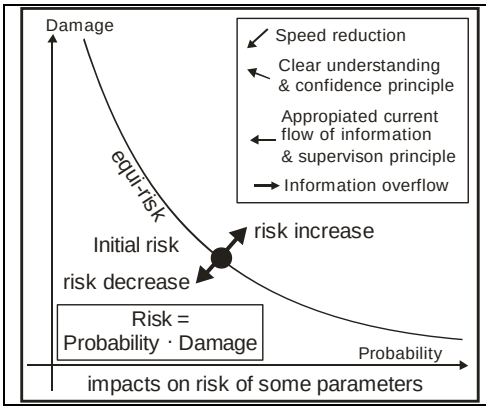
- high speed on the diverting point leading to either the asked/excepted route or the set route;
- obstacle located at short distance of the diverting point *(cf. l_{e_brake} - Fig. 1)*.

IMPROVEMENTS OF PROCEDURES AND EQUIPMENT

One can take action on factors in order to reduce the risk of a collision, in particular against parked vehicles. Some of them are shown in Figure 2 and discussed.

[6] *cf. Table 3*

Figure 2: Risk reduction factors

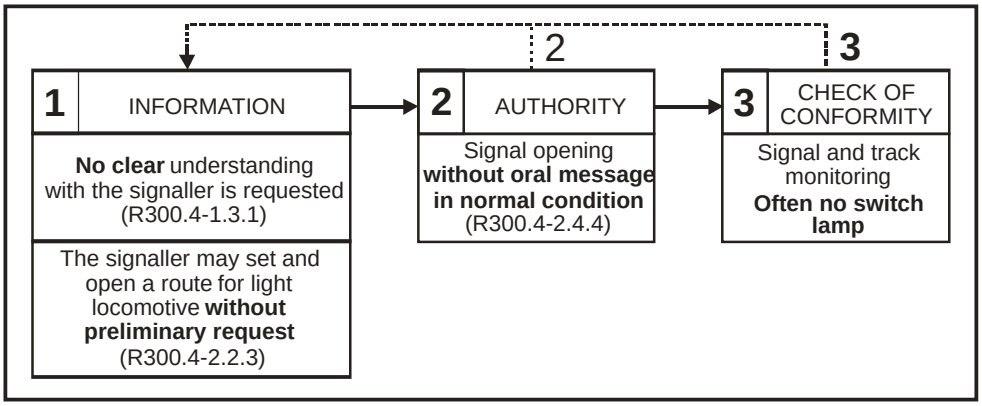


The risk is the result of the probability of an accident multiplied by the damage if this accident occurs.
From an initial situation, risk reduction can be obtain by:
- speed reduction;
- appropriate rate and quality of the information flow;
- clear understanding (even in case of less supervision).

Information overload can lead to miss the most important pieces of information and increase the risk

The first level of action is the improvement of the procedure as the current Swiss shunting regulations shows some failings. In particular, the feed-back loop, needed to stop the shunting move if something differs from what was foreseen, is very tenuous, as shown in Figure 3. When the signaller is requested to set a route, he often has no sufficient mental representation of the role of this shunting move into the whole shunting process. In some stations, tasks may be shared by more than one signaller, according to the station side, and it could be difficult for signallers to have to complete overview of the whole shunting process without clear explanations. When the signaller opens a route, an oral repetition of the route is unfortunately not requested. However, an oral repetition is able to produce a strong automatic comparison in the mind of the signaller between his three kinds of memories: the action memory (setting the route[7]), the visual memory (highlighting of the route) and the verbal memory (repeating the designation of the route). The oral repetition is not only a means for the signaller's self-control, but also it gives an input to the shunting staff in order to check if the set route matches the one that was decided.
Finally, without point position signals and only the #233 dwarf signal aspect, the driver/shunter is rather unable to detect if the next point leads to a free or an occupied track and rather unable also to determine if the route set is identical to the one which was asked or expected. Figure 4 shows some possible improvements of the information in the Swiss shunting regulations in order to increase the quality of the check of the conformity between asked/foreseen route and set route.

Figure 3: Current Swiss shunting regulation

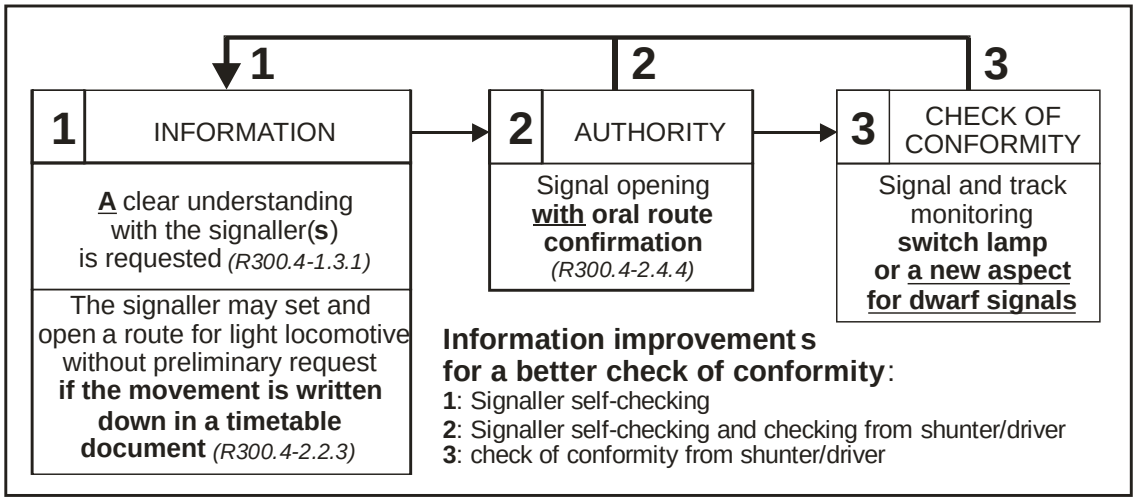


[7] in particular on topological operation tables

The proposed improvements deal actually with the three phases of a full shunting action:

1) Comprehensive explanations have to be given to all partners involved in the shunting move before the first movement agreement. The sole exception, for light locomotives, is acceptable if the movement foreseen was previously well-documented and known by both the signaller and the driver. This written information must contain, in particular, the information of an entrance on an occupied track if needed.
2) Each time that a dwarf signal is newly opened, the signaller should inform the shunting of the set route. It's quite important, not only for checking but to avoid SPAD if only a partial route is opened.
3) More information on the field has to be provided. Information about the entry on an occupied track has to be provided. That can be done either by creating a new aspect of the concerned dwarf signal or by an extended use of the GSM-R radio

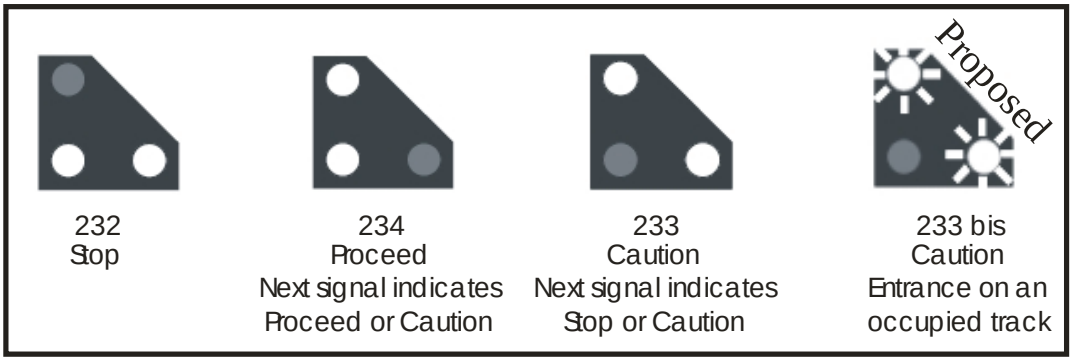
Figure 4: Some thinkable improvements of the Swiss regulation



Unfortunately, solution consisting to reinstall point position signals should be dismisses as too much lamps or signs would have to be observed at the same time (point position signals and dwarf signal). In marshalling yards or if shunting moves are initialized in only a few numbers of places, route indicators can help.

The Swiss dwarf signals are position light signals. The three lamps are white. A valid aspect requests that two of them lit simultaneously. So, three different valid aspects are possible.
If only one lamp lights, it is quite impossible to determine which lamp it is. Using a one lit lamp aspect to mean stop is too dangerous as, if this lamp is accidentally unlit, the risk to trespass the dwarf signal out is too high.
A fourth aspect can be obtained by the lighting of the three lamps simultaneously. In this case, this new aspect should be the most permissive one. Actually, if one of the three lamps is accidentally unlit, a more restrictive aspect has to appear. The main disadvantage of this solution is to change the meaning of the current proceed aspect (two white lights - vertical) into a more restrictive meaning, what is very confusing for experienced people.
In my opinion, the more convenient way to build a new aspect is to use the flashing effect.
The proposal is to flash the #233 aspect (two white lights - diagonal) to indicate the entrance on an occupied or a very short track, as shown in Figure 5.

Figure 5: A new aspect for the Swiss shunting dwarf signalling



The main advantages of this solution are:
- signal flashing is internationally used to request more attention;
- no adaptation of dwarf signals themselves is requested;
- the extra investment in the interlocking seems affordable in comparison with the reduction of the risk. Nevertheless a cost/benefit analysis has to be done.
- the new aspect can be progressively introduced without changing the meaning of the current aspects. Only when the interlocking is fully equipped, information than steady diagonal white lights doesn't lead to an occupied track can be added at the local regulation;
- a lower speed limitation can be associated with this new aspect.

Another way to give more accurate information to the driver on the state of the track ahead is to do it through the secured digital radio GSM-R.
Comparing the aspect of the dwarf signals of the set shunting route and the state of the related track circuits, interlocking could permanently transmit to the shunting move, though the radio, information concerning the route (free, occupied, ending on a short section) and the minimal free track length ahead of the move (sum of the length of the free track circuits ahead). As soon as this length falls to zero, either the shunting move is entering the last track circuit of the permitted route or it is entering the last track circuit before track circuit(s) occupied by parked vehicles.
It is clear that the implementation of this new device to help shunting movements would be much easier in stations already equipped by ETCS Level 2.
But no help can be directly expected from ETCS Level 2. In fact, the ETCS must run under the Shunting Mode (SH) to pass balises indicating stop in a shunting area. The list of balises, which shunting movements can pass, has to be known. From ETCS point of view, the shunting has no mission, ETCS will not give it any Movement Authority (MA) and train data are lost [9].
The only supervisions ETCS does, according to specifications, are to stop the shunting move if the border of the shunting area is trespassed, and to control the maximum speed. This speed restriction value is a national value [6].
As a consequence, current implementation of ETCS provides only a minimal supervision, which cannot impede collisions between shunting moves and a parked rail vehicle.
Nevertheless, in ETCS Level 1, if the main interlocking unit is connected with the balises concerned, the telegram "packet 44" can transmit the number of remaining free track

sections as well as a possible warning about "entry on an occupied track" to the shunting move. It is, of course, not very effective for freight reverse moves, where the balise's readers are under the locomotive, which is generally the last part of the shunting to pass a balise group.
Therefore, a specific device using the GSM-R protocol can help to secure the shunting move not only against parked vehicles but also against SPAD, what is much more frequent than could be expected [8].

Finally, according to Figure 2*,* speed is of great importance as it increases significantly the risk of collision by either the frequency (longer braking distance to stop when the driver gives an emergency braking order the train), and higher damage (higher kinetic energy involved in the collision).
Annex II shows, if the speed limit was 30 km/h instead of 40 km/h, that two of the five investigated collisions would have not happened and two others would have occurred at significant lower speed, regardless of the shunting rolling stock. With an initial speed of 20 km/h, none of the four collisions would have occurred.
A reduction of the speed at 25 km/h on points, as today in Germany, seems a good deal between short shunting route occupation and safety against collision.

CONCLUSION

The risk of colliding parked vehicles on a permitted but not expected route is significant and all economically sound measures to reduce this risk should be deeply investigated.
A first measure is to better involve the signaller in the whole shunting process: oral repetition by radio of the set route after each agreement, English as a common language, and son on.
A second measure, whose cost is only a little reduction of capacity, is to reduce the maximal speed on points from 30 km/h to 25 km/h if the dwarf signal shows "proceed carefully" until the driver/shunter responsible for the move has the complete assurance the points do not lead to an occupied track.
A third measure is to consider seriously the possibility of adding a new aspect to indicate entrance on an occupied or a very short section.
A fourth measure is to develop a shunting cab-signalling device using GSM-R to provide useful information about the set route.
Electronic interlocking and digital radio give a promising outlook to increase the safety of shunting moves without heavy investments in infrastructure. It would be a pity not to grasp this opportunity.

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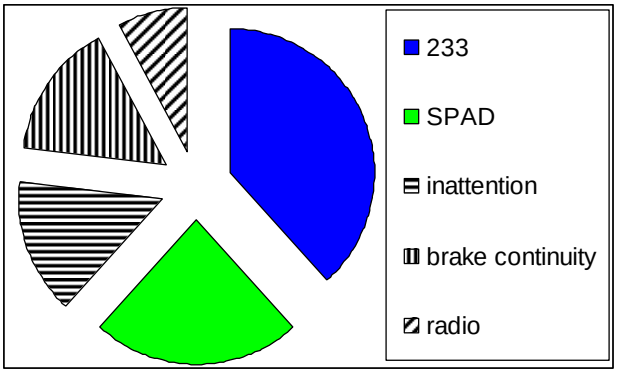
Annex I : Shunting accidents or near misses investigated by UUS

Table A1: Shunting accidents investigated by the Swiss Investigation Body UUS during the last 5 years

Date	Place	Draft sign.	Route observance	Consequence	Cause	Cost
25.02.2009	Cossonay	Yes	shunter	Derailment	drag shoe	n.a.
19.01.2009	Zürich RBL	Yes	driver	Derailment	unknown	60'000 €
28.12.2008	Bülach	Yes	driver	Derailment	points	n.a.
10.12.2008	Schaffhausen	Yes	driver	Derailment	SPAD	n.a.
02.12.2008	Biel RB	Yes	hump serv.	Collision	mistake	n.a.
09.06.2008	Rorschach	Yes	shunter	Derailment	drag shoe	n.a.
13.05.2008	Bern	Yes	shunter	Collision	inattention	330'000 €
10.05.2008	Zürich-RBL	Yes	hump serv.	Derailment	safety installat.	n.a.
29.04.2008	Biel RB	No	shunter	Derailment	points	200'000 €
25.04.2008	Mellingen	Yes	shunter	Derailment	SPAD	70'000 €
28.12.2007	Brugg	No	driver	Derailment	points	n.a.
30.11.2007	St Triphon	No	driver	Collision	mistake	60'000 €
02.08.2007	Arosa	Yes	shunter	Collision	radio	270'000 €
07.07.2007	Zürich Mülligen	Yes	hump serv.	Derailment	safety installat.	n.a.
08.06.2007	Schaffhausen RB	No	shunter	Collision	mistake	n.a.
01.06.2007	Zürich	Yes	shunter	Derailment	drag shoe	140'000 €
11.02.2007	Zürich	Yes	driver	Collision	SPAD	n.a.
08.01.2007	Zürich Herden	Yes	shunter	Collision	***233***	150'000 €
07.12.2006	Cossonay	Yes	shunter	Derailment	drag shoe	80'000 €
02.11.2006	Bülach	Yes	driver	Derailment	SPAD	120'000 €
27.10.2006	Brugg	No	shunter	Derailment	Point	40'000 €
15.06.2006	Zürich	Yes	driver	Collision	brake contin.	250'000 €
01.05.2006	Kaiseraugst	Yes	driver	Derailment	SPAD	170'000 €
28.04.2006	Thun	Yes	driver	Collision	SPAD	12'800'000 €
05.03.2006	Flamatt	Yes	driver	Derailment	mistake	130'000 €
28.02.2006	Solothurn	Yes	shunter	---	SPAD	0 €
18.01.2006	Solothurn	Yes	shunter	Near miss	SPAD	0 €
07.12.2005	Lausanne	Yes	shunter	Collision	SPAD	130'000 €
15.11.2005	Thun	Yes	driver	Collision	***233***	300'000 €
22.06.2005	Palézieux	Yes	driver	Collision	***233***	> 80'000 €
22.04.2005	Basel-Kleinhün.	No	driver	Derailment	unsuf. brake %	80'000 €
20.04.2005	Hüntwangen	Yes	shunter	Collision	SPAD	> 100'000 €
23.12.2004	Zürich GB	No	shunter	Derailment	drag shoe	130'000 €
18.08.2004	Zürich GB	No	shunter	Collision	mistake	90'000 €
29.05.2004	Biel	Yes	driver	Collision	***233***	200'000 €
18.05.2004	Bulle	No	driver	Collision	inattention	n.a.
27.04.2004	Zürich- RBL	Yes	driver	Collision	brake contin.	n.a.
31.03.2004	Zürich	Yes	shunter	Collision	radio	300'000 €
03.02.2004	Zürich	Yes	driver	Collision	***233***	270'000 €

Figure A1: Collisions investigated by UUS the last 5 years involving shunting moves according to causes



Annex II : Impacts of speed on collisions against parked vehicles

Four out of five collisions after a misinterpretation of the #233 aspect involved initial speeds above 30 km/h (*cf. Table 4*). If maximal speed was limited at 30 km/h, two of the five collisions would have been avoided and the two others would have happened at lower speed, reducing significantly the kinetic energy to be absorbed during the collision.

Figure A2: Maximum distance to stop (reaction plus brake equivalent time of 3 seconds - automatic brake pipe and relatively long composition)

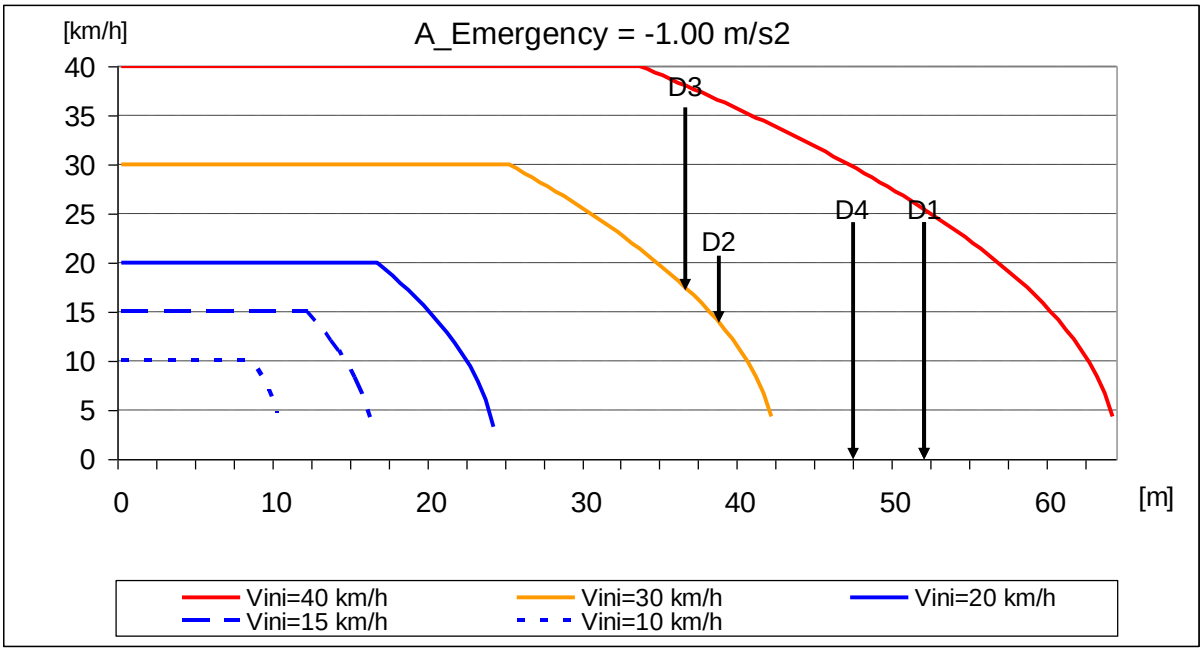
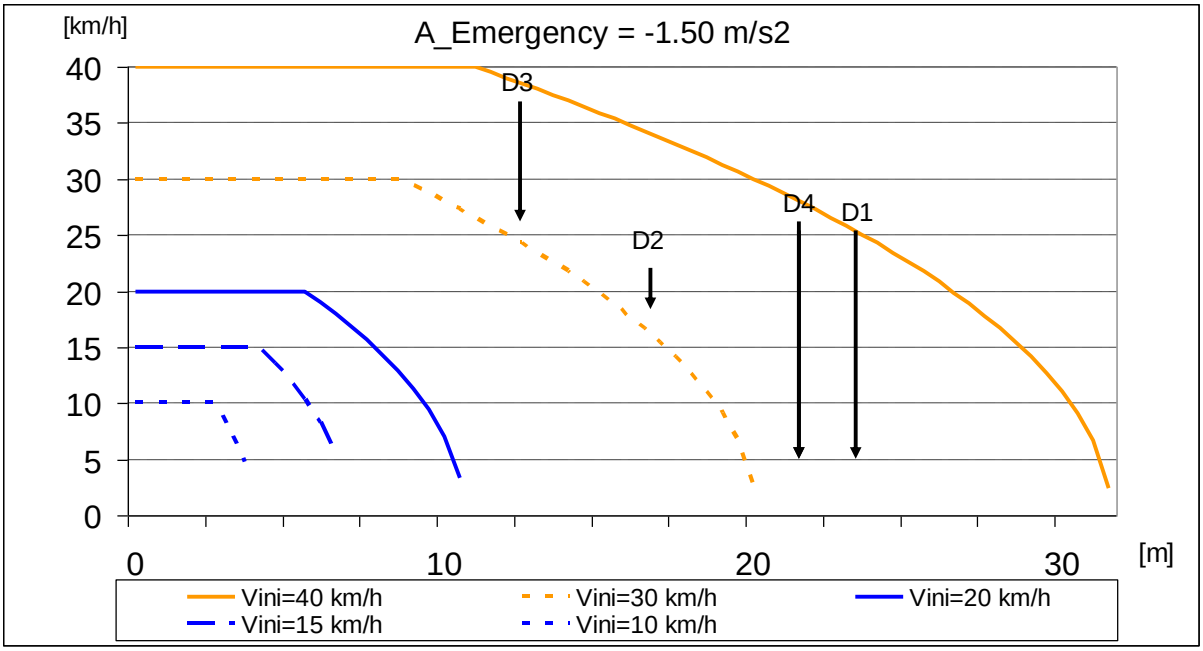


Figure A3: Minimum distance to stop (reaction plus brake equivalent time of 1 seconds - emergency and shunting braking - short EMU)


[km/h]
A_Emergency = -1.50 m/s2
40
35
30
25
20
15
10
5
0
D3
D2
D4
D1
0
10
20
30
[m]
Vini=40 km/h
Vini=30 km/h
Vini=20 km/h
Vini=15 km/h
Vini=10 km/h