OTIF

ORGANISATION INTERGOUVERNEMENTALE POUR LES TRANSPORTS INTERNATIONAUX FERROVIAIRES

ZWISCHENSTAATLICHE ORGANISATION FÜR DEN INTERNATIONALEN EISENBAHNVERKEHR

INTERGOVERNMENTAL ORGANISATION FOR INTERNATIONAL CARRIAGE BY RAIL

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(English only)

RID: **3rd Session of the RID Committee of Experts' standing working group**
(Berne, 20 and 21 May 2014)

Subject: **Cost/benefit analysis for proposal on crash buffers for tank-wagons intended for the carriage of dangerous goods**

Proposal transmitted by the Netherlands

SUMMARY

Executive summary: –

Action to be taken: Amendment of RID, as proposed in documents OTIF/RID/CE/GTP/2013/13 and OTIF/RID/CE/GTP/2013/15 (Netherlands)

Related documents:

- OTIF/RID/CE/GTP/2013/13 (Netherlands)
- OTIF/RID/CE/GTP/2013/15 (Netherlands)
- OTIF/RID/CE/GTP/2013-A, paras. 47-52 – report of the 2nd session of the RID Committee of Experts' standing working group (Copenhagen, 18 - 22 November 2013)

Introduction

1. At the previous session of the RID Committee of Experts' standing working group the Netherlands was asked for a cost/benefit analysis and examination of accident statistics in more detail in order to highlight the positive effects of its proposal concerning crash buffers.

2. As requested, the Netherlands has carried out such an analysis and examination, as shown in the annex to this document.

Proposal

3. The Netherlands would like to ask the standing working group for a decision on the amendment of RID, as referred to in documents OTIF/RID/CE/GTP/2013/13 and OTIF/RID/CE/GTP/2013/15.

A COST-BENEFIT ANALYSIS OF CRASHBUFFERS ON TANK WAGONS

IN CHARGE OF THE MINISTRY OF INFRASTRUCTURE AND
THE ENVIRONMENT OF THE NETHERLANDS

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ARCADIS

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Introduction

During the meeting of the Standing Working Group of the RID Committee of Experts in November 2013 in Copenhagen, a proposal from the Netherlands to expand the retrofitting of freight wagons with crash buffers was discussed. The OTIF Working Group requested the Ministry of Infrastructure and the Environment (I&M) of the Netherlands to investigate the pros and cons of their proposal to install crash buffers also on dangerous goods tankcars beyond the present scope of RID TE 22.

It is noteworthy to mention that crash buffers don't prevent rail accidents, but they can reduce damages and injuries considerably. This analysis will focus on the costs of installing crash buffers on freight wagons that carry dangerous goods that are or will be covered under RID TE 22 and the benefits of limited damage and injuries during accidents. Therefore we used information of accidents where freight wagons, equipped with crash buffers, were involved and accidents where no crash buffers were involved but where it's likely that crash buffers could have reduced damages.

According to the Regulations concerning the International Carriage of Dangerous Goods by Rail (RID), and in correspondence with EN 15551 and UIC Leaflet No. 573 (technical conditions for the construction of tank-wagons) specific classes of hazardous substances are indicated to meet provision TE 22. For example, on tank-wagons for the transport of toxic and flammable gasses (2T and 2F) buffers that can absorb energy of a collision had to be installed to the end of 2012. For new rail cars (manufactured since 2007) each buffer must absorb 400 kJ of energy, and 250 kJ for rail cars already in use.

1.1 PROPOSAL

Extend the requirement for crash buffers according to special provision TE 22 to wagons with other groups of dangerous goods (OTIF/RID/CE/GTP/2013/13 and OTIF/RID/CE/GTP/2013/15, transmitted by The Netherlands).

1.1.1 EXISTING CRASH BUFFER REQUIREMENTS

In RID crash buffers according to special provision TE 22 are already required for:

a) tank-wagons and battery-wagons constructed from 1 January 2005 for the carriage of toxic gases of Class 2;
b) tank-wagons constructed from 1 January 2005 for the carriage of substances of classes 3 to 8 carried in the liquid state, assigned to tank code L15CH, L15DH or L21DH (liquids of packing group I);
c) tank-wagons and battery-wagons constructed from 1 January 2007 for the carriage of flammable gases of Class 2;

d) tank-wagons constructed from 1 January 2007 for the carriage of substances of classes 3 to 8 carried in the liquid state, assigned to tank code L10BH, L10CH or L10DH (liquids of packing group I).

1.1.2 PROPOSAL EXTENSION OF CRASH BUFFER REQUIREMENTS

The intention of the proposal is to prescribe crash buffers for tank-wagons and battery-wagons for all gases and for all substances carried in the liquid state.

Proposal 1: Tank-wagons and battery-wagons constructed before 1 January 2007, for substances mentioned under 1.1.1 c and d, must be refitted with energy absorbing crash elements before 31 December 2018. ➔ Insertion in 1.6.3.27 (b): "*However, by no later than 31 December 2018, they shall be fitted with the devices defined in special provision TE 22, which shall however be capable of absorbing at least 500 kJ of energy at each end of the wagon.*
However, for tank-wagons and battery-wagons to be submitted to a periodic inspection between 1 January 2019 and 31 December 2021, this retrofitting may be carried out no later than 31 December 2021".

Proposal 2: Extension of TE 22 (in column (13) of Table A {Chapter 3.2} and insertion in in 1.6.3.27, for tank-wagons and battery wagons for:

- gases of Class 2 with classification codes containing the letter A or O and authorised for carriage in tanks and
- substances of classes 3 to 9 carried in the liquid state and to which tank code LGAV, LGBV, LGBF, L1.5BN, L2.65CN, L4BN, L4BH, L4BV, L4DH, L4DN, L4DV or L10BN is assigned in column (12) of table A of Chapter 3.2,

constructed before 1 January 2015 and which do not conform to the applicable requirements of special provision TE 22 of 6.8.4 in force from 1 January 2015, may still be used. *However, by no later than* .. etc (see above).

1.2 NUMBER OF FREIGHT WAGONS CONCERNED

To weigh things properly it is necessary to make clear how many freight (tank and battery) wagons are involved in this project. Therefore an overview of the number of freight wagons aimed for dangerous goods is necessary. To gather this information we've contacted the UIC, UIP, VTG, CEFIC and several carriers. With the information provided, we made an estimate of the number of freight wagons that can be expanded with crash buffers.

According to UIP/Annual report of 2012, the 14 largest national UIP associations own a total amount of wagons of **176,542**. One source implies that about 60,000 of those wagons carry dangerous goods.

The website of UIP states: *Founded in 1950, the UIP – International Union of Wagon Keepers, with its seat in Brussels, is the umbrella association of national associations from fourteen European countries, thus representing more than 250 keepers with approximately 180,000 freight wagons, performing 50% of the rail freight tonne-kilometres throughout Europe.*

Country	Association	Total number of freight wagons
Germany	VPI	62,566
France	AFWP	39,976
Switzerland	VAP	28,441
Poland	SWP	7,617
Austria	VPI	7,124
Spain	FAPROVE	5,194
Belgium	BeWag	4,907
Slovak Republic	ZVKV	4,689
Czech Republic	SPV	3,979
Great Britain	PWF	3,619
Sweden	SPF	2,828
Netherlands	NVPG	2,322
Italy	ASSOFERR	2,183
Hungary	MVMSZ	1,097
	Total	176,542

Table 1: UIP member associations and their fleets.

In the meantime (april 2014) UIP represents keepers for approximately 200,000 freight wagons.

By combining information of several documents and informants, especially with the aid of the UIP, we have made an estimation of the number of tank cars that are relevant for this study. It is an estimation and not a precise inventory because of uncertainties and because of other aspects, such as wagons that are too old or too bad to be used in practice. One example of an uncertainty is the meaning of ‘Europe’ or ‘European’ in an arbitrary text. However, we believe that in the near future a better overview will be present when the sector has completed the new RSRD^2 project and its database (*Note*: the ‘2’ is part of the project name as a superscript, and no footnote number). RSRD^2 is a large step forward in the inventory of number, identity and properties of freight vehicles[1] and hopefully also in the details on crash buffers. For now the estimation is as follows:

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[1] See for example UIP Annual reports or presentations of Thomas Heydenreich, Project Manager RSRD^2, rsrd@th-heydenreich.de.

Item	UIP + non-UIP	UIP only
Total number of freight wagons throughout Europe	600,000	200,000
Percentage herein of tank cars (all types)	25%	45%
➔	150,000	90,000
Percentage of *RID* tank cars only	90%	90%
➔	135,000	81,000
Percentage to be equipped in future under TE 22 including the Dutch proposal (=> added: A and O gases, and most liquids)	80%	90%
➔	**108,000**	**73,000**
Percentage already regulated under TE 22 in RID 2013	20%	25%
➔	21,600	18,250
Remaining percentage due to the Dutch proposal	**80%**	**75%**
➔ Max. number of tank-wagons to be retrofitted	**86,400**	**54,750**

Table 2: Estimation of consequences for existing vehicles involved in the Proposal.

Thus, *about 86,000 tank-wagons* are potentially involved. However, some of those will have an age that it is unattractive to keep them in service.

For new tank-wagons, not yet built, a retrofitting operation is not relevant. Equipping these new wagons with crash buffers can be a regular process step with relatively less costs. In fact, as long as the physical properties (weight of the buffer etc.) are appropriate, the difference between traditional buffers and crash buffers is a simple price difference, regulated by market factors. For the moment one of the informants estimated this difference 3000 € per wagon (for 4 buffers).

For a complementary insight in the logistic use of tank cars and tank container wagons throughout the EU, the Eurostat database gives relevant data per member state on the transport performance, see on: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=rail_go_dnggood&lang=en). One can see, that Germany, Latvia, Poland, Estonia, Romania, Lithuania and France (in this order) had the highest volumes (ton km's).

1.3 INFORMATION SOURCES

To gather the right information we've contacted UIC, UIP, OTIF, ERA, CEFIC, and several manufacturers or owners of the freight wagons, manufacturers of buffers, and also individual members of the CEFIC and further on the EBA and the German Ministry. Without their information we couldn't make this analysis and we thank them for their help.

2

Crash buffers

2.1 TECHNICAL SPECIFICATIONS

In general two types of crash buffers exist for Rail Tank Cars (RTC's), covering the TE 22 provision.

- Crash buffers that can handle 250KJ. These are the crash buffers that can be installed on older RTC's.
- Crash buffers that can handle 400KJ. These are the crash buffers that can be installed on new RTC's

The crash energy is absorbed by expanding the buffer sleeves or by other technical principles.

Technical requirements to install crash buffers were not mentioned but the installation of crash buffers have to be carried out according to RID regulations. They can be bolted onto the vehicle with four bolts. These have to be tightened to a pre-approved tightening torque which is denoted by the train builder. One of the manufacturers states the following on the company website: "*The external dimensions and attachment flange of the crash buffer are identical with those of a standard side buffer complying with the rail industry standard UIC 526-1. Therefore, the crash buffer can be mounted to all vehicles that have been designed for standard side buffers in accordance with this standard. It can be used for the protection of high capital cost modern railway vehicles, as well as a retro-fit onto existing older railway stock where enhanced protection is desired*."

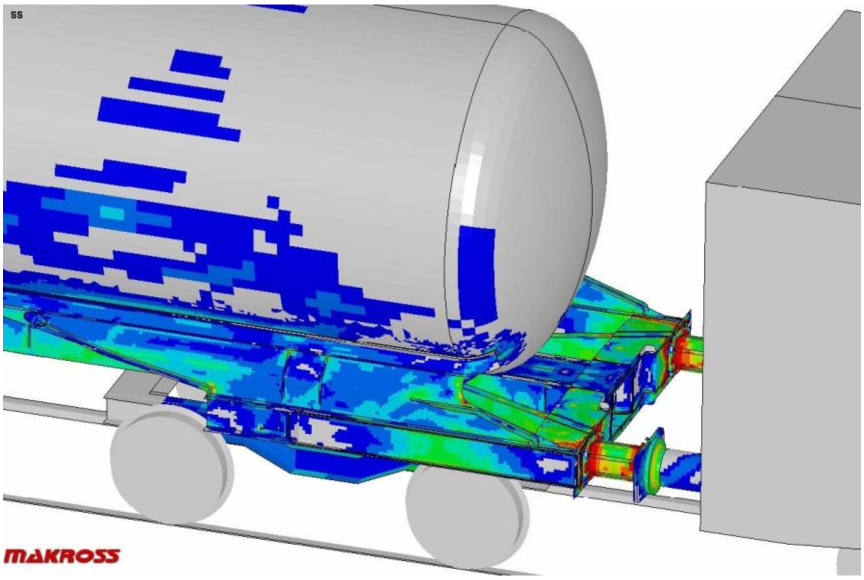

Figure 1: Stress dissipation in a filled tank-wagon (80 tons) at a collision at 36 km/hr [9].

Figure 1 shows an example, and no more than that, of a calculation of the stress dissipation. Be aware that in practice several construction principles and forms of tank cars can be found; besides, the velocity during a real collision can of course differ from just 36 km/hr.

2.2 QUALITY AND TESTS

Lots of publications in scientific papers or for conferences can be found to learn more about the physical and dynamic properties of several types of crash buffers and the principles used to absorb the energy. A few examples are in the reference list of this report, published by EST, Axtone and Wascosa. For a further acquaintance with this theme also videos of tests, or animations can be found on Internet. It is also interesting to mention that initiatives for the improvement are sometimes incorporated in more comprehensive tankcar safety projects or programmes, e.g. CeSa[2], 'Safe Tank Car ®' or 'SafeTrain'. One of the properties that is important for the overall business case is the weight of one buffer. We mention here two examples, the so called "Suprapuffer G2 of EST weighs 170 kg and the Voith-product weighs 140 kg.

2.3 COST OF CRASH BUFFERS

To examine the price of crash buffers we've contacted several manufacturers and suppliers of crash buffers as well as companies that either possess or rent RTC's that have crash buffers installed.

Product name	Company	Based in	Example of 400kJ-buffer	More information	Related with
Axtone	Axtone	Poland	IP400-C	www.axtone.eu www.crashtechnology.eu www.oleo.co.uk/products/rail/crash-buffers	Oleo
EST	Eisenbahn-SystemTechnik	Germany	G1-200 K G2-100 MB	www.eisenbahn-systemtechnik.de ; www.crash buffer.com	Knorr-Bremse
Innova	Azoma	Romania	Crash buffer 400 kJ	www.innova-systech.com	
Voith	Voith + SMW	Germany	VSSM-105-400	www.voith.com	
AP	AP Industrie	France	Crash Guard	www.acieries.com	

Table 3: Overview of manufacturers of crash buffers.

According to different sources crash buffers are available for roughly twice the price of a conventional buffer. The crash buffer can have an eye-catching colour, but that is not a general way of recognition.

The prices of crash buffers covered under EN15551 vary between €1000,- and €1600,- per buffer. For this analysis we use the amount of **€ 1500,-** per buffer on RTC's. This is the price that is mentioned in several e-mails and articles we received. Because each wagon needs four crash buffers the total price per RTC comes to **€ 6000,-.** This is a rough average for the market price nowadays, it can be foreseen that a real large expansion of the production and sales of buffers results in price reductions. See also the order form of EST in Appendix 4.

To make a more realistic overview of the costs of crash buffers a distinction must be made between the costs of installing crash buffers on old(er) existing RTC's and installing crash buffers on new RTC's.

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[2] CeSa: **C**hemie Kesselwagen für **e**rhöhte **S**ichheits**a**nforderungen

According to information from different sources the retrofitting of older RTC's is more expensive because of several additional costs. Some of those additional costs can however be reduced. These additional costs and possible ways to reduce those costs are displayed in the following table.

Additional costs retrofitting older RTC's	Possible ways for reducing costs
Older RTC's can't be just retrofitted with crash buffers that can handle more than 250 kJ. Crash buffers that can handle (for example) 400 kJ can only be mounted on wagons that are prepared for those buffers. The mechanical resistance of the chassis needs to be enforced. Costs will have to be made to enforce the undercarriage for those RTC's.	It is necessary to define with the manufacturer[3] (ECM registered companies) which type (250 kJ or 400 kJ) could be installed depending of the underframe design. Example: This was already required in the past by the RID when retrofitting ammonia RTC built before 2005.
Older RTC's will have to be geared into decommissioning for some time. Depending on how many RTC's can be retrofitted at once the costs will differ. Most companies rent cars for a specific time.	Retrofitting the RTC's **on site**! They also make repairs and do the inspections. ▪ In this case you can save time because there's no transport to the maintenance and back. The time that is saved can be used for the usual business. ▪ Retrofitting can be done during the regular maintenance. This also saves time and money. ▪ Because the RTC's can be used directly after retrofitting, maintenance and inspection, there's no problem with capacity of the workshops.
Modifications like adjusting the undercarriage and installing crash buffers, should be done in registered workshops, via the Entity in charge of maintenance (ECM[4]).	
Legal required dossiers for each RTC have to be maintained in good order. The documents and technical drawings have to be changed. Crash buffers will become part of the maintenance regime.	
The number of RTC's on which crash buffers can be installed at the same time is dependent on the capacity of the workshops.	
Older retrofitted cars that have an adjusted undercarriage and newly installed crash buffers need to be tested by rail inspectors (inspections according to RID and/or rail transport legislation). This will add to the price of installing crash buffers on older wagons.	
For cars that are near the end of their life span retrofitting is less useful and therefore more costly.	After the life span of the RTC, the crash buffer can be reused on new/other RTC's.
	The remaining 'normal' buffers after retrofitting RTC's with crash buffers can be used on other cars that don't carry dangerous goods, or they can be resold. Only when there is a market for old 'normal' buffers.
	The reparation costs of RTC's can be lower after an incident: ▪ the crash buffer reduced the damage on the RTC, so the repair costs will be lower ▪ with less damage, and shorter recovery period, the RTC can be used sooner.

Table 4: Additional costs of installing crash buffers on older RTC's

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[3] Some manufacturers with expertise: GreenBrier - WagonySwidnica S.A (PO), Graaf -Elze (DE), Magyar – Dijon (FR), Titagarh (Arbel-Fauvel – Douaix) (FR), Atelier Orval and GATX.

[4] ECM, see Regulation 445/2011/EC.

It is clear that installing crash buffers on older RTC's is more complex and therefore more expensive. But there are ways to reduce those costs. If older RTC's will be retrofitted we expect the total costs per RTC will be € 6000 for the buffers plus € 2000-3000 for additional costs.

Several users of RTC's (for example chemical companies) denoted that in most cases the costs of crash buffers are passed on in the rent for the RTC's per day. The order size of the extra costs is 2 € /per day / per RTC.

2.4 MARKET DEVELOPMENTS

To have an idea of the efforts by the shippers from the (petro)chemical industry to meet the regulations and their possible voluntary intentions to do more, we have sent a small questionnaire to a number of CEFIC-members. CEFIC itself recommend the further use of crash buffers in their documentation on risk assessment. Reactions were given by several companies.

Company	Type of DG[5]	Tank code	Classif. code	
Shell	RTC's for UN 1040 (EO) equipped RTC's for UN 1280 (PO) in 2014 New RTC's for UN 2055 (styrene) ordered with cr.buff.	L4BN LGBF	2TF	
AKZO Nobel	RTC's for UN 1017 (chlorine) equipped		2TOC	1 MJ buffers each (= extra performance)
DSM	RTC's equipped RTC's equipped	L10BH L4BH		(90% 400kJ, 10% 250 kJ)
Yara	RTC's for UN 1005 (ammonia) equipped RTC's for nitric acid equipped		2TC	Nitric acid: voluntary
SABIC	All RTC's equipped (also the non-mandatory ones)			
Ineos	RTC's for propylene, butadiene, raffinate and crude C4	Several		53% of fleet equipped with cr.buff.
DuPont	RTC's equipped where required			26% of fleet equipped

Table 5: RTC's being or to be equipped with crash buffers. In most cases the number of wagons is between 150 and 400.

> Quotation of AKZO Nobel: *The new RTCs are constructed according to the latest RID legislation and on top of that additional technical safety improvements are added to achieve the highest passive safety standard within reasonable boundaries for chlorine transports of Akzo Nobel outside the Netherlands. VTG, as the lessor of these RTCs, has developed, in close cooperation with Akzo Nobel, so-called "crash protected rail tank cars" (CPRs), of which Akzo Nobel currently has 60 in service. Extra safety features include a special reinforced underframe, automatic load sensitive brakes, an additional buffer override protector, energy absorbing buffers of 1 MJ each, and additional crane hooks to ease rescue operations when needed. By introducing this newly developed CPRtype rail tanker, Akzo Nobel has initiated a standard for safe chlorine transport by rail that is unprecedented in RTC safety history and higher than any pre-existing national standards.*

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[5] DG = Dangerous good(s) [also else in this report]

3

Incidents

3.1 EXAMPLES OF INCIDENTS WITH CRASH BUFFERS ON DAMAGED WAGONS

One of the best examples of an incident where crash buffers prevented a bigger disaster is the incident in Barendrecht 2009 near Rotterdam [OTIF-1.8.5, see ref. a2]. This prompted the Dutch division of SABIC to recommend the introduction of crash buffers on a wide scale, not only in the Netherlands, but also in the European area. It is noteworthy to mention that in this case the buffers were installed on a voluntary basis. The train transported a series of wagons with natural gas condensate (UN 1268; HIN 33) and also two other compounds (UN 2014 and 1751).

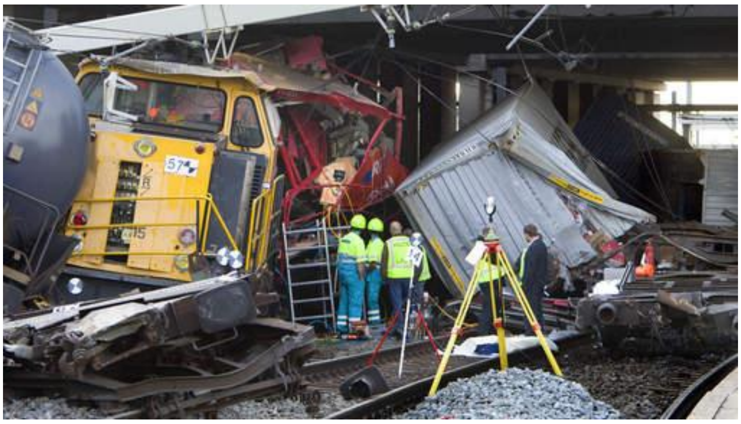

Figure 2: Collision in Barendrecht (NL, 2009).

The safety element of the crash buffers that were fitted to the tank cars in Barendrecht absorbed a certain part of the released energy and was instrumental in ensuring that the tanks and load remained intact, thus helping to prevent greater damage. A much larger accident was really near-by on that moment, because a passenger train entered the location and stopped just in time, on a very short distance.

Figure 3: Crash buffer on one of the UN 1268 wagons after the collision in Barendrecht.

But this example is not the only one where the advantage of the crash buffer is clear. In the transport of chlorine two other examples are interesting to regard. In both cases no chlorine escaped.

Ledsgard, Sweden (2005) and Woippy, France (2010).

Quotation from Base Chemicals (Sweden) “The high energy crash buffers performed satisfactorily, some (but not all) were used to full capacity”

Figure 4: Incident with chlorine transport in Ledsgard (Sweden).

Figure 5: Overbuffering of a chlorine wagon (uncleaned) in Woippy (France).

Other incidents where crash buffers certainly of presumably were present in the wagons damaged, had not always such a relatively beneficial effect. In the next paragraph a series of accidents will be mentioned, some of which with large consequences (injuries and damages), some with less. However, the presence of crash buffers is seldom clear from the official accident investigation reports.

3.2 LARGE INCIDENTS WHERE TANK-WAGONS WITH DANGEROUS GOODS ARE INVOLVED, OVERVIEW

3.2.1 OVERVIEW OF LARGE INCIDENTS WITH FREIGHT TRAINS TRANSPORTING DANGEROUS GOODS

For data and overviews of serious railway incidents, especially derailments and collisions, several public sources are available. We have screened them for this investigation. Logical sources are:

- ERAIL Database[6] of ERA
- RID 1.8.5 reports of OTIF

For national overviews (France and Germany)
- Database ARIA {http://www.aria.developpement-durable.gouv.fr/}
- Database GUNDI {http://www.gefahrgut.de/gundi/ ; only until the end of 2006} ; website EBU (footnote 12).

More generic overviews
Together with some general Internet-queries and with safety information already available in the Netherlands, it was possible to make a list of top events that contains accidents characterized by criteria such as:
- Release of dangerous goods in large quantities, i.e. loss of the contents of at least one tank.
- Involvement in the accident of tank cars with the (proven) presence of crash buffers of the type meeting the RID TE 22-provision.
- Interesting from an analytical perspective.

A considerable number of accidents is known where certain quantities of liquefied gasses or of liquids were released due to damage to one or more of the tanks in the freight train. If no limitation is made to the year of occurence the list is rather long. Looking at the website of GUNDI and using the query term 'Kesselwagen' (railway tankcar) gives the backgrounds of the incidents such as those in Schönebeck, Elsterwirda, Hannover, Bad Münder, Trier and Osnabrück that in fact prompted the formation of the RID Tank- und Fahrzeugtechnik Working Group and as one of the results the introduction of crashworthy buffers. However, for the reason of age and topicality on the one hand, and for geographical spreading and safety relevance on the other hand, we select only accidents since 2007 and accidents that have had consequences that exceed the local attention or national news. This means that accidents can be missing that were found in the source databases.

It is not necessary to evaluate a complete list of accidents, because the notion that the course of an accident usually *changes in the right direction* when crash buffers are present, suffices as a general viewpoint. Nevertheless, it would be better when investigation boards and/or inspectorates in their reports will in the future in a standard way comment on the wagons that are damaged and the type of buffers that are found on these wagons.

Several of the accidents mentioned in the following Table are briefly evaluated, see in paragraph 3.2.3.

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[6] See on: http://erail.era.europa.eu/

Nr.	Date	Location	Incident type	Dangerous good(s)-DG	Effect of the DG	Remarks
1	23-01-2007	Tornesh (D)	Derailment	UN 1750 (chloroacetic acid)	Loss of 22 tons in environments	DG not in tank-wagon, but in tank container
2	16-07-2007	Lviv (Ukr)	Derailment	UN 1381 (Yellow phosphorus)	6 wagons released their products: huge fire and toxic cloud	
3	12-11-2008	Artix (Fr)	Derailment	UN 1301 (vinyl acetate)	Loss in soil	
4	27-01-2009	Stewarton (UK)	Derailment	Diesel, gas oil and kerosene	Loss in environments, local fires	
5	29-06-2009	Viareggio (I)	Derailment	LPG	Huge explosion and fire	> 30 people killed and > 100 injured.
6	24-09-2009	Barendrecht (NL)	Collision between two, nearly three trains	UN 1268 (natural gas condensate)	Tanks survived heavy collision	Performance of crash buffers very helpful
7	24-11-2009	Orthez (Fr)	Derailment	LPG, small leak	Relatively small	
8	04-03-2010	Glons (B)	Collision of locomotive and freight train	Flammable gas (likely LPG)	Tank damaged but survived	
9	15-03-2010	Stuttgart (D)	Derailment in MY	Diesel fuel	300 kg loss	Quotation: "*One corner of the buffer beam of the second tank-wagon pierced the rear-facing tank wall of the overturned wagon. Hence a 4 cm hole was made in the tank wall*"
10	07-04-2010	Gelsenkirchen (D)	Derailment	UN 1090 (acetone)	Relatively small leakage (environmental)	
11	22-05-2010	Neufchateau (Fr)	Derailment	Phenol	Loss in environment	
12	08-11-2010	Bialystok (Pol)	Two trains collision (both with RID-goods)	UN 1202 (diesel) and UN 1965 (LPG)	Explosions, fires in many wagons	First loss of flammable substance caused by a buffer penetrating the diesel oil *fuel* tank of a locomotive ; two persons wounded
13	22-12-2010	Woippy (Fr)	Collision of two train parts in MY near	Chlorine (uncleaned tanks)	No loss of DG	

			Metz			
14	14-01-2011	Kijfhoek (NL)	Collision at 30 km/hr of two train parts in MY near Rotterdam	Ethanol	Fire and other (gas)tanks threatened	Nat. Safety body mentions crash buffers as a wise measure for this type of incidents
15	21-09-2011	Bleicherode (D)	Collision between two freight trains	Gas oil (UN 1203) ; DMF (UN 2265)	Fire and 80 ton loss UN 1203 (and also 200 l DMF).	Driver wounded
16	04-05-2012	Tintigny (B)	Collision between two trains in/near tunnel	UN 2348 (butyl acrylate) a.o.	Small leakage	
17	11-05-2012	Godinne (B)	Collision between trains on open track	UN 2078, 1715, 2348, 1131	Small	Invest. rep.: TE 22 is relevant as a measure
18	04-05-2013	Wetteren (B)	Derailment	Acrylonitrile (UN 1093) (+ uncleaned tanks for butadiene)	Fires, explosions, toxic good in sewage	Person died by toxic inhalation (via sewage system). Accident under investigation.
19	08-05-2013	Rostov (Ru)	Derailment	Gas oil, diesel oil, propane	Explosions and huge fire	27 persons wounded Possibly fire in locomotive as initiating event
20	05-02-2014	Kirov (Ru)	Derailment	Flammable gas	Explosions and huge fire	

Table 6: DG-related incidents, overview. Orange coloured marking of heaviest accidents.

3.2.2 THE COURSE OF LARGE INCIDENTS

Large incidents in practice with freight trains transporting (amongst others or only) dangerous goods are especially collisions and derailments. Although other large incidents can occur that are threatening in a comparable way, e.g. nearby external fires or spontaneous tank failures[7], most actual accidents are caused by a primary collision or derailment. These main causes can be subdivided:

- Collision[8] between two rail vehicles (internal rail collision)
- Collision between rail vehicle and road vehicle (level crossing collision)
- Collision between rail vehicle and any type of obstacle
- Derailment due to a vehicle shortcoming
- Derailment due to an infrastructure shortcoming
- Derailment due to dynamic circumstances, especially train speed and/or curvature

NOTE: the whole *sequence of events* determines the resulting gravity of the accident:

Regular service ➔ **Railway event (collision, derailment..) ➔**	➔ Loss of DG ? ➔ Ignition? ➔ Casualties/injuries ?

A heavy derailment can still be without loss of containment (think for example of the incident in Visé in Belgium in 2000). Crash buffers are meant to shift the consequences from the one arrow to the other in the left direction.

Any large freight rail incident is unique and can't be considered as a typical scenario. The uniqueness of the accident is the sum of all the elements together that determine the exact movements and physical contacts that take place in the seconds or minutes after the initial cause. These elements are manifold and varying in character and influence, such as: speed of the train(s), route of the train, braking situation, security system of the train, lay-out of the infrastructure, type and construction of the locomotive and the wagons, quality of the rolling stock and infrastructure, (obstacles in) the immediate environments, level (height) of the railway infrastructure compared to the environments etc.
Summarized, a train that collides or that derails is usually going to make a very complex and intensive number of manoeuvres (and mechanical/physical contacts). How longer the train, the more details in the dynamic consequences. Thus, it is certainly not an easy job to predict the exact course of an arbitrary large train incident. In fact it is a local, unique event where the individual movements of all the wagons concerned are hardly controllable. After the incident

- the whole train can still be straight;
- a small or big part can be capsized;
- train parts or train rolling stock fragments can be ended up outside the railway area into the public space.

Looking to buffers only, a description of all the detailed movements they make individually is very difficult. The fate and especially the influence of buffers in collisions and derailments is often relevant and in several cases crucial. Usually, in most incidents buffers are anyhow involved in the rapid sequence of mechanical events during a collision or a derailment. In any freight train, buffers of the one wagon and the

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[7] Example: the fire in a freight train at Schärding in Austria (May 2006).

[8] Note: accidents can escalate from collisions to derailments or from derailments to collisions, but here we look to the *first* event (primary cause) in the series of events.

next are so close to each other that any disturbance of the regular train movement almost inevitably leads to a direct contact between these buffers.

Figure 6: Mutual position of two opposite buffers. Note: the markings (yellow triangles) are indicative of the level of impact during long-time operation: here still as new.

The direction of the 'main, central movement' of the train as a whole (forward in most collisions ; varying from forward to side wards in most derailments) determines whether the very first interaction and contact surface between two opposite buffers is small or large. If it is small, a second possibility is the overclimbing of one of the buffers over the other; this is the domain of RID TE 25. If it is large, the collision energy and its mechanical consequence in the mutual buffer collision are greatly dependent on the identity of the buffers themselves. Classical types[9] are destroyed much easier than crashworthy buffers and the remaining collision energy can still do much harm to the chassis and/or other wagon elements such as the tank. This highly undesirable result is the key reason to enlarge the scope of TE 22 to many classes of dangerous substances. Every fire, explosion or toxic cloud that is avoided thanks to the presence of crash buffers is a very attractive prospect. The difference between the occurrence of a loss of content on the one hand and the prevention of that loss on the other is a very important safety result. A collision or derailment ending with a huge effect such as a big fire and a number of victims, is incomparable with the same event ending with only much mechanical (and economical) damage.
The statement that crash buffers have the potential to diminish accident consequences, especially the difference between loss and retention of the chemicals, is the justification to invest in these devices.
The truth of this statement is not doubted by the authors of this report.

3.2.3 BRIEF COMMENT ON ACTUAL ACCIDENTS AND THE POSSIBLE INFLUENCE OF CRASH BUFFERS

3.2.3.1 *VIAREGGIO - 2009*

In the overview in the Table in 3.2.1 a variety of accidents is given, some of them with really large consequences. The derailment in Viareggio, due to a rolling stock shortcoming, could not be avoided by any buffer type. But can we say more about the effect? Here we can't be precise, because it is impossible to give a straightforward, reliable answer to the question. However, we can present the main characteristics of the derailment.

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[9] See RID 6.8.3.1.6: the minimum required energy absorption capacity of regular buffers is 70 kJ.

The derailment in Viareggio is the most severe incident with dangerous goods on rail in the previous years. We here consider the derailment as a railway incident, independent of the final consequences. As far as the information is correct, the train travelled with a speed of about 90 km/h and passed the station of Viareggio when an axle broke off and the train derailed. After the locomotive a series of gas tank cars was transported and the first one, the crucial one that finally failed, tilted and finished against a very strong element of the infrastructure (a vertical, sharp post). According to the investigation board, the train drove 370 meter from the derailment point, before the first five tanks overturned. Besides, the first tank car was reported to be streaking along 100 meters before the wall of the tank ruptured.

The exact course of this wagon that was built in 2004, was a fatal one. Could it be different when crash buffers were present? Nobody can say, we think, but we cannot exclude for 100% the hypothesis that a slightly different course was possible. In this example *every meter* and *every degree of the direction* of the movement has its meaning. Because the other tilted tank cars survived the violence of the derailment, the sharp post and its precise position were the key factors in the loss of containment event.

The question is whether $X_T = X_{T2}$ and whether $X_C = X_S$ per definition, or not.

Interestingly, the Italian delegates in the RID Standing WG recently also made a hypothetical argumentation about a better outcome in Viareggio. They argued that a *derailment detector* could have prevented the loss of the flammable gas [14a, 16].

3.2.3.2 STEWARTON – 2009

This complex accident is worth an in-depth review on the possible role of crash buffers (which were not present). The train derailed on a collapsing, old railway bridge. The tank-wagons, some of which lost their contents (fuels), contacted each other and moved in several directions. The buffers contributed to the overall damage: "*The same pattern of developing movement continued onto wagon 5 and the wagons that followed, with the motion becoming so severe that the adjacent ends of the wagons started to override. This resulted in a number of the buffers getting knocked off, and tanks being punctured by drawhooks (paragraph 85). The drawhook on wagon 7 cut a gash in the tank of wagon 6 that was over 1 metre high providing further evidence of the size of the dip that had developed*".

Figure 7: Consequences of the Stewarton accident.

The total damage costs of this derailment must have been very high (infrastructure, rolling stock, freight, environmental pollution etc.). It is imaginable that considerable damage cost reduction was possible when all cars were equipped with crash buffers.

3.2.3.3 *BARENDRECHT – 2009*

Once again a few words about the incident in Barendrecht. The course of this accident seems to be positively influenced by the broad presence of crash buffers. One train long all wagons with the flammable liquid *natural gas condensate* were equipped with them and they have done their job: moderating the huge energy due to the collision and lowering the overall violence of the blast.
If one should imagine that the buffers had been of the traditional type, and that one or more of the tanks had been penetrated, a worse course was expected because a passenger train just came close. This accident has been widely reported to the OTIF-members in a RID 1.8.5-message.

3.2.3.4 *GLONS – 2010*

The collision in Glons (or *Glaaien* in the Dutch language) was not that big that a large investigation has been made by the authorities. This collision where a single locomotive collided with the rear of a freight train did not result in a fire or a small explosion. Of course that is a comforting idea. Why was the result a limited pattern of damage? It is interesting to check whether crash buffers were responsible for the course, because it is not mentioned in the sources that were studied.

3.2.3.5 BIALYSTOK – 2010

Figure 8: Impression of the fire in Bialystok.

Where two freight trains, both with a lot of tank cars with dangerous goods hit each other, the situation is critical. And indeed, this incident[10] in Poland escalated. The huge fire took place near the city and – happily – only two injured people were the effect of the collision. In an English report the main findings are available. The type of collision is worth mentioning, because it is a sideward collision. The third car (from the tail) of one train was hit by another. Side collisions are, in general less beneficial in the context of crash buffers.

The report says that first loss of flammable substance was caused by a buffer penetrating the diesel oil *fuel* tank of a locomotive. This buffer seems to be a classic one and therefore the force it can develop is important to analyse. Although in this case in first instance the tank of the locomotive failed and not the tank with one of the transported hazardous goods, this primary event is of course the determining factor for the later consequences.

3.2.3.6 WOIPPY – 2010

The incident in Woippy (near Metz) with emptied, uncleaned chlorine tank-wagons, did not attract much international attention. As far as we can see it is an important example of a positive influence of crash buffers. This is only an estimation. If so, the example is worth mentioning in this context.

3.2.3.7 KIJFHOEK – 2011

The fire on the largest marshalling yard in the Netherlands took place because ethanol was ignited after a collision between short sets of tank cars in the (hill) shunting process, at a speed around 30 km/hr. The heat of the fire threatened other tank cars in the immediate vicinity.

The collision could have a much better course, i.e. no fire at all, when the ethanol wagons had been equipped with crash buffers. The Dutch Government has already indicated this possibility in a proposal in the RID Committee.

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[10] Video, see on: http://www.tvn24.pl/wiadomosci-z-kraju,3/ratuja-resztki-paliwa-splonelo-17-wagonow-i-dwie-lokomotywy,151617.html

3.2.3.8 *BLEICHERODE – 2011*

In Bleicherode, a town in the neighbourhood of Göttingen, a collision resulted in a fire and evacuation.

The collision is in this case a special one. One freight train collided with the second one, while both trains moved in the same direction and on the same track: a typical head-to-tail collision, but now with two driving trains instead of one waiting train. The front train, running with a speed of 33 km/h, consisted of a long series of railway tankcars, filled with fuel (gasoline, UN 1203). The second train hit the tail at a speed of 81 km/h. The last two tank cars lost their contents, the front train broke in pieces. The total economic damage, according to the report, was about € 9 million.

This accident is really interesting for the question whether crash buffers would make a difference. This type of collision is suitable for the maximum benefit of the buffers, because both trains moved on the same track (in a straight line). The collision energy can be dissipated in the best possible way when all tank cars in the front train would have been equipped. Although it is not mentioned in the report, the assumption is that the flammable liquid wagons (LGBF required) were not equipped with crash buffers.

3.2.3.9 *TINTIGNY – 2012*

A head-to-tail collision in a railway tunnel took place in Tintigny (Wallonia). This accident had no serious bad human consequences (only a scent of acrylates), but is worth mentioning because here the presence of crash buffers would likely have a positive influence to reduce the large mechanical damage.
The speed of the second train was 28 km/h, which is typically interesting to have a good result when crash buffers would have been installed.

3.2.3.10 *GODINNE – 2012*

The collision in Godinne has been discussed in the RID Committee already, because of a proposal and a RID 1.8.5-report from Belgium. This concerns also a head-to-tail collision. The local rail infrastructure is in a curve and the houses are very close to the tracks. The freight train transporting dangerous goods was waiting. The tail of that train contained a number of tank cars and one other wagon with metal girders in between (which happened to be a large disadvantage, in fact). The tank cars were filled with varying chemicals, i.e. UN 2078 (toluene diisocyanate) {L4BH}, UN 1715 (acetic anhydride {L4BN}, UN 2348 (butyl acrylates) {LGBF} and UN 1131 (carbon disulphide) {L10CH}. Also two empty, uncleaned tank cars were in the tail row. Carbon disulphide is relevant for TE 22, dependent on the age of the vehicle. In Godinne the wagon for carbon disulphide was built before 2007 (Accident investigation report, page 103). Crash buffers were not present. The second, incoming train had a speed of 84 km/h.

Because of the complexity of the collision, in a curve, it is not easy to judge how far crash buffers would have been successful in mitigating the damage. The train speed was that high that physical damage occurred inevitably. See in 3.2.4 for some rules of thumb.

3.2.3.11 *WETTEREN – 2013*

The accident in Wetteren in Flanders concerned the derailment and overturning of several tank-wagons with UN 1093 (acrylonitrile) and one with empty, uncleaned butadiene and the involvement of a second empty butadiene gas wagon.
Because the investigation report has not been published until now, it is - for the moment - not sensible to consider the possibilities of damage reduction.

3.2.4 OTHER INCIDENTS WITH HAZARDOUS GOODS TRAINS

The heavy Russian incidents in Rostov and Kirov were not evaluated yet. In a later stage it can be valuable to look at the details. The search in the ERAIL database gave other replies of incidents with dangerous goods trains that were not selected in this study. We mention them briefly.

Date	Location	Type	ERAIL-number
01-06-2006	Karjaa (Fi)	Collision with obstacle	FI-142
23-01-2007	Tornesch (D)	Derailment	DE-55
04-08-2007	Siilinjärvi (Fi)	Derailment	FI-367
07-02-2008	Budafok (Hu)	Derailment	HU-473
08-02-2008	Turku (Fi)	Derailment	FI-428
01-03-2008	Kokkola (Fi)	Derailment	FI-494
15-05-2008	Kokkola (Fi)	Derailment	FI-496
17-07-2009	Bruchmühlen (D)	Derailment	DE-745
19-02-2010	Kilpilahti (Fi)	Collision with obstacle	FI-872
05-03-2010	Herlasgrün (D)	Derailment	DE-870
22-05-2010	Neufchateau (F)	Derailment	FR-930
16-07-2010	Valega (Por)	Derailment	PT-962
04-04-2011	Asper (No)	Fire in rolling stock	NO-1123
17-10-2011	Dehylov (CZ)	Collision with obstacle	CZ-1274
13-04-2012	Maasvlakte (NL)	Trains collision	NL-1412

Table 7: Incidents with trains with dangerous goods

This is not the entire list. The EU-statistics of 2010 and 2011 show:

Type	Year	EU total
Accidents involving at least one railway vehicle transporting DG	2010	54
	2011	28
Accidents involving at least one railway vehicle transporting DG in which DG are **NOT released**	2010	17
	2011	19
Accidents involving at least one railway vehicle transporting DG in which DG **ARE released**	2010	37
	2011	9

Table 8: Dangerous goods incident, according to ERA-statistics (EU-members).

Finally, the EBA (Eisenbahn Bundesamt in Germany) was asked for examples of other incidents where the presence of crash buffers was involved. The examples give an idea of the practice:

- 08-04-2008, Hamburg-Unterelbe
  A trainset consisting of a locomotive and 22 gas tank-wagons, 20 tanks filled with UN 1965 (mixture A, Butane), 2 tanks filled with UN 1012 (Butylene), was involved in an incident during a shunting operation. The last gas tank-wagon hit a buffer stop at a speed of 15 km/h while backing the train. As a result the buffer stop was shifted about 20 m and the last two gas tank-wagons (both filled with UN 1965) derailed. The last wagon was equipped with crash buffers, the second one was not equipped with crash buffers. Due to overriding of buffers the front end of the last tank was hit by the buffers of the second wagon, but not penetrated.
  Three out of four crash buffers of the last wagon were not triggered (yellow markers still visible), just one of the two crash buffers hitting the buffer stop was triggered. There was no leakage of dangerous goods, nobody was injured.

- 02-07-2013, Düsseldorf-Derendorf
  A trainset consisting of a locomotive and 12 gas tank-wagons, each one filled with UN1077 (Propene), was involved in an incident. Five wagons derailed, one of them turned over. One out of four crash buffers of the wagon which turned over was ripped off, the three other crash buffers were not triggered. The crash buffers of another derailed wagon were not triggered as well. It is assumed that track geometry faults led to this incident, the investigation is not finished yet.
  There was no leakage of dangerous goods, nobody was injured.

- 26-10-2013, Gladbeck-West
  A trainset consisting of a locomotive and gas tank-wagons, empty, uncleaned (UN1077, Propene) was involved in an incident. The locomotive of the outbound trainset collided with another inbound freight train by side-impact after passing a red signal. The first gas tank-wagon derailed and turned over, the first bogie of the second wagon derailed as well. It is assumed that the crash buffers of both wagons were triggered and partly destroyed, the investigation is not finished yet.
  There was no leakage of dangerous goods, the train driver was seriously injured.

These examples stay often outside the daily news. The show us that more and more incidents can be found in which the buffers play a certain role [see also ref. 9, page 44-46]. And slowly the appreciation can grow that some 'little incidents' are indeed little instead of large because the course of the incident was influenced. This is worth considering as a point of attention.

3.2.5 RULES OF THUMB

The indicative judgment whether crash buffers are effective to prevent damage, especially damage concerning loss of containment out of tank-wagons, is possible by some rough rules.

- How lower the speed, the more positive effect. Train speeds (above 12 and) below 40 km/h are the better circumstances.
- Collisions give more hope than derailments.
- Head-to-tail and head-to-head collisions are better than side wards collisions.
- Straight routes are better than curved routes.
- Derailments ending with trains still straight (not capsized) are more hopeful.
- Marshalling yards with a gravity sorting system (hills or humps) can benefit especially.

We emphasize the last rule. Uncontrolled movements in the yards, due to failures, can have large advantage when crash buffers are present. The speeds that are found in marshalling yards during the hill operations are seldom above 30 or 40 km/hr. Crash buffers can absorb nearly all energy when – unintentional – collisions take place here.

It is noteworthy to mention that also incidents with higher speeds undergo the advantage of the buffers. Because tanks (i.e. wall thickness and other protection aspects) are built to withstand an impact during a collision or another physical contact, the *speed limit* that the protection no longer works *is enhanced*.

3.3 CONCLUSION

In retrospect, the conclusion is that several accidents in the past could have had a much better ending when crash buffers would be present on the railway tank cars involved. Less fires, less damage and other disadvantages such as environmental pollution are plausible by analysing these accidents. Although the entire proof cannot be given, the examples of Kijfhoek, Bleicherode and others show that a reduction of collision energy is an attractive option to reduce the overall effects of large rail accidents.

4

Analysis

4.1 COSTS

What	Amount (see Chapter 1)
Total amount of freight wagons	600,000
Total amount of freight wagons that carry goods covered under the scope of the proposal	108,000
Freight wagons that carry goods covered under the scope of the proposal that are already provided with crash buffers	21,600
Freight wagons that carry goods covered under the scope of the proposal that and should be provided with crash buffers in the future	**86,400**

Table 9: Numbers of relevant tankcars.

Retrofitting of 4 buffers (400 kJ or 250 kJ type) and average costs of the inspection and other accompanying actions is taken as just one amount (see Chapter 2): Four pieces per vehicle, together 6000 €, plus extra costs of 1500 €[11] **=> 7500 €.** This is a maximum, leaving out the possibility of price decreases due to rise of production scale.

- For crash buffers on all freight wagons covered under the scope of the proposal the maximum amount will be 86,4000 x 7500 € = **648 million euro**.

It is realistic to think that not all old wagons will be retrofitted and that we can leave out 10% of the fleet. The amount will than proportionally go down with nearly 65 million euro. The same can be done for the price itself thanks to large production series and large orders. If the price is lowered by 10%, the total will end up between 500 and 550 million euro.

4.2 BENEFITS

The benefits have several faces, i.e. a pure economic and especially also a non-economic character. In this report we will not specify costs of human lives lost. We also will not specify the worth of reputation of the (petro)chemical and the rail transport sectors. Nor the meaning of soil pollution towards animal and plant life. These aspects are involved in the benefits, but not specified in euros.

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[11] The amount of 2000-3000 € extra costs (in par. 2.3) can be lowered to 1500 € or less by following one or more of the suggestions, mentioned in Table 4.

Benefits in reduced damages towards rolling stock, infrastructure, freight etcetera can be estimated, although the costs of all the accidents that happened and of all the 'future' accidents are not known in a quantitative measure comparable to the costs given in 4.1 above.

Large accidents represent inevitably high costs. An accident with costs above 5 million euro's is certainly not rare, every year in Europe plus the COTIF-member countries outside Europe several accidents occur with such high costs. It depends which costs one includes (e.g. the evacuation of people, the transport to hospitals, the barricade and not-use of the railway line, etc. etc.) how high the final amount is.

For the discussion in the RID Working Group it is sensible to realize that the reduction of the overall accident costs when all tank cars will be equipped is certainly a considerable portion of the crash buffer costs. We will work that out in the next paragraphs.

4.2.1 COSTS OF INCIDENTS

Although every accident is unique due to the precise scenario that happened, it is possible to show a number of costs that are expected when a freight train with dangerous goods on board ends up in a serious accident, such as a collision or a derailment. The actual costs when the hazardous good(s) is (are) indeed lost, imply often costs related to:

- Damage to rail vehicles
- Damage to infrastructure and other assets of railway parties
- Damage to property of third parties
- Loss of (the economic value of) the hazardous good(s)
- Loss of (the economic value of) other freight
- Call and deployment of the fire brigade and other emergency services
- Out of service of train traffic on incident line
- Disturbance of external train traffic
- Disturbance of road traffic
- Injuries
- Evacuation, reception and care
- Damage to animal life
- Damage to plant life and to edible vegetables
- Further environmental damage
- Sewage pollution
- Accident investigation
- Assurance activities
- Juridical affairs
- …

All of these costs can be of major or minor importance. Many of the items include a variety of direct and indirect costs. As an example, the deployment of emergency services can grow to a large operation with use of special extinguishing media, continuous measurements of air and water quality and the installation of field hospitals.

To have an idea of damage costs the – public – reports of the German Investigation body, the EUB (Eisenbahn-Unfalluntersuchungsstelle des Bundes[12]) are helpful. We mention a few examples from the cost estimates concerning accidents with dangerous goods trains.

Location and year of accident	Type of accident	Total costs	Among which
Bad Münder [2002]	Collision of two trains ; loss of UN 2023 (epichlorohydrin) ; explosion	10,883,000 €	4,500,000 € (soil pollution/renewal) 2,800,000 € (vehicles) 1,850,000 € (infra) 1,150,000 € (diverse)
Osnabrück [2004]	Derailment in station ; loss of UN 1965 (LPG) ; fire	4,576,600 €	1,565,000 € (infra) 1,101,600 € (vehicles)
Bleicherode [2011]	Collision of two trains (head to tail) ; loss of UN 1203 (gas oil) ; fire	8,950,000 €	4,000,000 € (locomotive) 2,000,000 € (infra) 1,500,000 € (environmental)
Nürnberg [2009]	Derailment, tank car (empty, uncleaned) with UN 3266 (corrosive, basic liquid); no loss of DG	632,609 €	283,048 € (vehicles) 300,000 € (infra)
Herlasgrün [2010]	Derailment and internal buffer override of cars with UN 1230 (methanol) and UN 2014 (sol. of H_2O_2) ; no loss of DG	573,000 €	Infrastructure (3 switches and 330 meter track) and vehicles

Table 10: Estimated costs of some accidents in Germany

The Table shows that DG release can cause a large difference. The difference will be elaborated (§ 4.2.2). Because environmental cost items (such as soil clean-up or exchange) are among the highest contributions, liquids are very relevant as group of chemicals that can augment accident costs.

4.2.2 INFLUENCE OF CRASH BUFFERS

The best thinkable influence of crash buffers in the incident costs is *the transition point between a typical railway accident* alone (collision, derailment), and *an escalation* due to the loss of a hazardous good. Escalated accidents of that kind have strongly raised damage costs, and for the purpose of a clear discrimination between typical and escalated incidents the cost figures are classified into three categories and five rankings (see Table 11).

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[12] See on: http://www.eisenbahn-unfalluntersuchung.de

Cost item	DG not released	DG released (no fire or explosion)	DG released (fire and/or explosion)
	← Influence of crash buffers, in general		
Damage to rail vehicles	🟧	🟧	🟥
Damage to infrastructure and assets	🟧	🟧	🟥
Damage to property of third parties	🟩	🟩	🟧
Loss of (the economic value of) the hazardous good(s)[13]	⬜	🟥	🟥
Loss of (the economic value of) other freight	🟩	🟩	🟧
Call and deployment of the fire brigade and other emergency services	🟨	🟥	🟥
Out of service of train traffic on incident line	🟨	🟧	🟥
Disturbance of external train traffic	🟨	🟧	🟧
Disturbance of road traffic	🟩	🟨	🟧
Injuries by DG	⬜	🟨	🟥
Evacuation, reception and care	🟨	🟧	🟥
Environmental damage[14]	🟩	🟥	🟥
Sewage pollution	⬜	🟨	🟨
Accident investigation	🟨	🟧	🟧
Assurance activities	🟨	🟨	🟧
Juridical affairs	🟩	🟧	🟥
INDIRECT COSTS			
Company reputation	🟩	🟨	🟧
Media involvement	🟩	🟨	🟧
Political and administrative impact and operations	🟩	🟨	🟧
Societal impact	🟩	🟨	🟧

Table 11: Incident outcome, and as a derived entity, the possible influence of crash buffers, applied as a ranking factor.

⬜	🟩	🟨	🟧	🟥
No costs	Low costs	Substantial costs	High costs	Very high costs

4.2.3 ANALYSIS

The information from several sources gives enough data to make a careful, indicative calculation about the benefits of crash buffers.

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[13] Loss of the content of one tank means on the average 50 x [price in € per tonne]. Indicative: 40,000 to 100,000 €, dependent on the identity of the DG.

[14] Damage to animal life and to plant life are left out as separate cost items.

Starting points

- In the ERA area (say: the EU) the number of reported accidents with DG release in 2011 is 9. We assume that this is only a part of the real number.
- Countries following the RID but being outside the EU contribute as well.
- ➔ The yearly number of relevant incidents with DG release is assumed to be 20 in the whole RID-region.
- The expected costs of large accidents with DG release are 4 millions of €'s higher than without DG release. The virtual benefit is 4,000,000 €.
- The crash buffers (if equipped on a large scale) have an estimated average influence of 20% to prevent escalation from DG retention towards DG loss (see rules of thumb in §3.2.5 and examples such as Kijfhoek).

- The yearly number of large accidents with trains with one or more DG wagons, but without DG release is assumed to be 80 in the RID-region.
- The expected costs of large accidents without DG release can have a reduction due to less overall damage of 10%. Overall costs per incident are estimated to be 500,000 €.

With these starting points, the calculated benefit per year is:

20 x 0,2 x 4,000,000 = 16,000,000 € [for DG release accidents]
\+ 80 x 0,1 x 500,000 = 4,000,000 € [for accidents without DG release]

Altogether, savings of 20,000,000 € per year are foreseen.

If the investment costs of the complete retrofit-operation programme (somewhat above 500,000,000 €)[15] are indeed realistic, a period of about 25 years corresponds to the levelling of costs and benefits.

4.3 RECOMMENDATIONS

For this moment recommendations are a bit early. However, evaluating the accidents that were studied we like to mention two points of attention to think about:

- Much better registration of the presence and role of crash buffers in accident reports by the NSA's (national safety authorities) or inspectorates/investigation bodies.
- Protection of (freight) locomotives by crash buffers as well.
- Installation of a central international box-office (counter) for crash buffer safety matters.

4.4 CONCLUSION

The estimation of costs of retrofitting crash buffers to the broad range of gas and liquid tank-wagons comes to a maximum of 648 million euro and a realistic amount of 500 to 550 million euro. The estimation of the exact financial benefit is difficult but in its essence attractive. Yearly savings of 20 million euro are foreseen.

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[15] See §4.1

Appendix 1 References

Nr.	Document
[1]	International Union of Wagon keepers a.i.s.b.l., Annual report 2012 (p. 29).
[2]	"Unfälle, Zwischenfälle, Beinaheunfälle – Konsequenzen für den sicheren Gefahrguttransport" [Wascosa] {CST, Wien} (Oct. 2012).
[3]	TE 22 + TE 25: "New engineering solutions for tank-wagons: over-ride and roll-over protection", Car Fleet 72 (3), p. 4-7 (2103).
[4]	J. Conrad, "RID 2009", Gefährliche Ladung, p. 36-39 (02/2008).
[5]	"Technische Massnahmen für noch mehr Sicherheit, Gefahr/Gut, p. 18-21 9Feb. 2006).
[6]	"Guidance on the design, construction and testing of standard rail tank cars for the transport of chemicals in bulk" {CEFIC} (2013).
[7]	"Reale Unfälle von Fahrzeugen mit EST Crashpuffer" (www.crashpuffer.de/p75.htm
[8]	"A comparative study from a competition perspective of mileage-related accidents caused by technical failures in vehicles/rolling stock and resulting in personal injury" {hwh for UIP and VPI} (Oct. 2013).
[9]	S. Schneider, "Crash buffers in day-to-day service: Experiences and economical benefits" {EST, LOSTR/Dolni Dunajovice} (March 2010).
[10]	"Durchführung des 4g Auflaufversuchs in Deutschland" [EST Eisenbahn-SystemTechnik, Berlin (Nov. 2008).
[11]	"Technical condition for the construction of tank-wagons" [UIC 573] (Apr. 2008).
[12]	www.crashtechnology.eu
[13]	For a broad review of crash technology up to 2003: "Literature review of rail vehicle structural crashworthiness" {Rail Safety & Standards Board ; ITLR-T12004-001} (2004).
[14]	Copenhagen minutes: OTIF/RID/CE/GTP/2013-A ; [14a] Viareggio; paragraphs 97-100.
[15]	Dutch crash buffer proposal: OTIF/RID/CE/GTP/2013/13 and OTIF/RID/CE/GTP/2013/15
[16]	Italian view on Viareggio incident and derailment detection: Copenhagen 2013, Inf. 3 and Inf. 15.
	Some specific accidents:
[a1]	"57 Woippy", Prév.Sécurité 116, p. 73 (March/Apr. 2011).
[a2]	"Report rail accident at Barendrecht", {OTIF/RID/CE/GT/2010/2; Berne} (Apr. 2010).
[a3]	REPORT No . PKBWK/2/2011, on investigation into Cat . A04 serious accident that occurred on 8 November 2010 at 05.30 hrs in Białystok station {State Commission for Investigation of Railway Accidents, Resolution No. 12/2011}
[a4]	Viareggio: M. Costa, "Accident occurred in Viareggio, June 29th 2009" {OTIF meeting, Roma, 11-13 April 2012}
[a5]	Godinne: Report 1.8.5 {OTIF/RID/CE/GTP/2012/1} (Aug. 2012).
[a6]	Kijfhoek: {OTIF/RID/CE/GTP/2012/8} (Sept. 2012).
[a7]	Stewarton: 'Derailment of a freight train near Stewarton, Ayrshire" {RAIB} (Jan. 2009).
[a8]	Lists of rail transport accidents: via http://en.wikipedia.org/wiki/Rail_accidents. Many investigation reports: via http://erail.era.europa.eu/

Appendix 2 RID TE 22

{RID, 6.8.4}

"TE22 In order to reduce the extent of damage in the event of a collision shock or accident, each end of tank-wagons for substances carried in the liquid state and gases or battery-wagons shall be capable of absorbing at least 800 kJ of energy by means of elastic or plastic deformation of defined components of the subframe or by means of a similar procedure (e.g. crash elements). The energy absorption shall be determined in relation to a collision on a straight track.
Energy absorption by means of plastic deformation shall only occur in conditions other than those encountered during normal conditions of rail transport (impact speed higher than 12 km/h or individual buffer force greater than 1500 kN).
Energy absorption of not more than 800 kJ at each end of the wagon shall not lead to transfer of energy to the shell which could cause visible, permanent deformation of the shell.
The requirements of this special provision are deemed to be met if crashworthy buffers (energy absorption elements) that conform to clause 7 of standard EN 15551:2009 (Railway applications – Freight wagons – Buffers) are used and if the wagon body satisfies clause 6.3 and sub clause 8.2.5.3 of standard EN 12663-2:2010 (Railway applications – Structural requirements of railway vehicle bodies – Part 2: Freight wagons)."

{RID, 1.6.3.27}

(a) Tank-wagons and battery-wagons
– for gases of Class 2 with classification codes containing the letter(s) T, TF, TC, TO, TFC or TOC,
and
– for substances of classes 3 to 8 carried in the liquid state and to which tank code L15CH, L15DH or L21DH is assigned in column (12) of Table A of Chapter 3.2, constructed before 1 January 2005 and which do not conform to the applicable requirements of special provision TE22 of 6.8.4 in force from 1 January 2005 may still be used. However, by no later than 31 December 2010, they shall be fitted with the devices defined in special provision TE 22, which shall however be capable of absorbing at least 500 kJ of energy at each end of the wagon.
However, for tank-wagons and battery-wagons to be submitted to a periodic inspection in accordance with 6.8.2.4.2 or 6.8.3.4.6 between 1 January 2011 and 31 December 2012 this retrofitting may be carried out not later than 31 December 2012.
(b) Tank-wagons and battery-wagons
– for gases of Class 2 with classification codes containing only the letter F, and
– for substances of classes 3 to 8 carried in the liquid state and to which tank code L10BH, L10CH or L10DH is assigned in column (12) of Table A of Chapter 3.2,
constructed before 1 January 2007 and which do not conform to the applicable requirements of special provision TE 22 of 6.8.4 in force from 1 January 2007, may still be used.

See also TU 38 in RID 4.3.5

Appendix 3 EN 15551

Number of Standard:	**CSN EN 15551+A1**
Released:	**2010**

This European Standard defines the requirements for buffers with 105 mm, 110 mm and 150 mm stroke for vehicles or units which use buffers and screw coupling at the coupling interface with other interoperable rolling stock. It covers the functionality, interfaces and testing procedures, including pass fail criteria, for buffers. NOTE Typically, buffers with a stroke of 105 mm are used on freight wagons and locomotives, buffers with a stroke of 110 mm are used on coaches and locomotives and buffers with a stroke of 150 mm are used on freight wagons. It defines the different categories of buffers, the space envelope, static and dynamic characteristics and energy absorption. It includes a calculation method to determine the minimum size of the buffer head to avoid override between buffers. It defines the static and dynamic characteristics of the elastic systems. ***It also defines the requirements for buffers with integrated crash elements (crashworthy buffers) for tank-wagons only according to RID****. The requirements of this European Standard also apply to locomotives and passenger coaches which have to meet the crashworthiness requirements of EN 15227 for buffers in normal service only. The properties for the energy absorbing function are defined in EN 15227 and the requirements specified in Clause 7 for tank-wagons according to RID are not applicable to locomotives and passenger coaches. Diagonal buffers are excluded from this European Standard. For vehicles which have to comply with crashworthiness requirements (locomotives, cab cars or passenger coaches according to EN 15227, tank-wagons according to RID), typically crashworthy buffers (buffers with a deformable housing and/or the need for an opening in their mounting flange) or buffers which form part of a combined system consisting of a special buffer (e.g. middle flange buffer) and a deformation element are used.*

Appendix 4 Order form (example)

Pos.	Description	Unit price [€]	Comment
1	Crash buffer G1-200 R ZCP05.06-C100000-06, EBA06A16C Energy absorption capacity per vehicle end 500 kJ Weight: 119 kg/crash buffer	**1,613.00**	Acceptance test cert. 3.1 acc. to EN 10204 RAL 2003 pastel orange Owner code: "CRSC"
2	Crash buffer G1-200 K ZCP05.06-C100000-07, EBA06A16D Energy absorption capacity per vehicle end 800 kJ Weight: 121 kg/crash buffer	**1,676.00**	Acceptance test cert. 3.1 acc. to EN 10204 RAL 2003 pastel orange Owner code: "CRSC" The vehicle structure strength must be tested.

Table 12: Relevant part of order Form for EST, 2011, see on:

http://www.crsc.ch/en/pdf/Download_crash_buffer_pool_CRSC_eV_E.pdf.

Colophon

A COST-BENEFIT ANALYSIS OF CRASHBUFFERS ON TANK WAGONS

CLIENT:

In charge of the Ministry of Infrastructure and the Environment of the Netherlands

STATUS:

Final

AUTHOR:

Cees Smit
Anja Katuin
Gijsjaap Pruis

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ARCADIS NEDERLAND BV
Piet Mondriaanlaan 26
P.O. Box 220
3800 AE Amersfoort
The Netherlands
Tel +31 (33 4771 000
Fax +31 33 4772 000
www.arcadis.nl
Dutch Trade Register 09036504