Development of the Future Rail Freight System to Reduce the Occurrences and Impact of Derailment

D-RAIL

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D1.2

Report on Derailment Economic Impact Assessment

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Executive Summary

The objective of D-RAIL's Work Package 1 is to provide a comprehensive review of recent freight derailments, to identify causes leading to these, and to understand the economic and social impact.

The first step was to gather information and conduct a review of project partner countries' freight train derailments happening in the period 2005-2010. Using this accident data, a Derailment Database has been created to capture several aspects of derailment causes including infrastructure, rolling stock and operation. An overview of data sources and rankings of derailment causes are presented in Deliverable D1.1.

Deliverable D1.2 provides details on the impact of freight derailments, including an assessment of the economic impact. Data sources were European databases EUROSTAT and ERADIS, information from project partners' databases and information from previous reports, studies and papers.

From the analysis of derailment impact in this deliverable, a number of observations can be made for modelling derailment costs:

- There are 500 derailments per year, of which 7% (35 derailments) involve dangerous goods.
- There are, on average, 2 fatalities per year and 3 serious injuries per year, at costs of 1.5M€ per fatality and 0.2M€ per serious injury, so the human cost is 3.6M€ per year. This is equivalent to a human cost of 7200€ per derailment.
- Environmental clean-up costs are negligible except in the 7% of derailments involving dangerous goods. If the minimum cost per dangerous goods derailment (250000€) is assumed here, this is equivalent to 17500€ per derailment.

Based on this, the human cost and environmental cost add a fixed cost of 24700€ per derailment, independent of the type of derailment. However, this is an average value, and could be thought of as, for example, six severe derailments per year, each incurring costs of 2M€ (rather than 500 derailments per year, each incurring the cost of 24700€ per derailment).

In data collection, the costs were split into two major groups:

- Direct costs, meaning just railway asset costs of infrastructure and rolling stock that are damaged during or after a derailment.
- Indirect costs, including e.g., disruption cost (delay minutes, etc.), fatalities and injuries costs, legal and litigation costs, third party damage, environmental (could include post-accident clean-up operation, etc.), attendance of emergency services, public dangers (hazardous cargo), loss of cargo and freight.

The data collected in D-RAIL indicates an 80%/20% split of direct costs between infrastructure and rolling stock.

For calculating the total impact in cases where only direct costs are known, the direct cost should be multiplied by a factor – ERA's cost benefit analysis model gives a factor of 2.5. Data for the USA indicate this factor to be 1.8 - 2. Analysis of the data provided by infrastructure managers in the D-RAIL project suggests that this factor may be much lower (only 1.33) but likely varies considerably between countries.

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Glossary

CBA	Cost benefit analysis
DDD	Derailment detection device
DG	Dangerous goods
DNV	Det Norske Veritas
ERA	European Railway Agency
ERADIS	European Railway Agency Database of Interoperability and Safety
ERTMS	European Rail Traffic Management System
EUROSTAT	The statistical office of the European Union
FRA	Federal Railroad Authority (USA)
GB	Great Britain
HABD	Hot Axle Box Detector
HF	Human factor
KVB	Contrôle de Vitesse par Balises ('Speed control by beacons')
LCC	Life cycle cost
ME	Million Euro
NIB	National Investigation Bodies
NSA	National Safety Authorities
RGS	Railway Group Standard
RSSB	Rail Safety and Standards Board
SMIS	Safety Management Information System
S&C	Switches and Crossings
UIC	International Union of Railways
WP	Work package

1 Introduction

Work Package 1 of D-RAIL provides a comprehensive review of freight derailments over the period of 2005-2010. This builds on the recent work by DNV for the European Rail Agency, as well as past studies by UIC, and by RSSB of derailments in the UK.

This work package includes two deliverables. Deliverable D1.1 provides a summary and database of derailments with the focus on identifying the most common causes; these results feed into WP3 which will model and analyse derailment causes in greater depth. Deliverable D1.2 focuses on an assessment of the economic impact; this will feed into cost benefit analysis in WP2 and economic analysis (LCC) in WP7.

D-RAIL Deliverable D1.1 categorized European, USA and Russian derailments according to the categories of causes selected by DNV, with the addition of one extra cause: 'Human factors'. Different rankings of the causes were developed, based on number of derailments, cost of derailments (based on preliminary cost data), etc. The final ranking of derailment causes for Europe does not include 'Human factors,' or 'Unspecified' or any sub-categories marked 'other'. The reason for these categories being dropped is that they are not technical causes. Further work in D-RAIL will concentrate on analysing existing technologies, improving them or developing new ones to combat main derailment causes. Ranking is based on the average number of derailments (as share of total) in each category or sub-category. Additionally, third-level categories have been merged.

The list of top derailment causes is:

1. [Rolling Stock] Axle shaft, journal or bearing failure
2. [Infrastructure] Misalignment: track gauge
3. [Rolling Stock] Wheel failure
4. [Operations] Skew loading (wagon wrongly or partly loaded)
5. [Infrastructure] Track twist fault
6. [Infrastructure] Cyclic top; Misalignment: cant
7. [Infrastructure] Rail failures
8. [Rolling Stock] Suspension failure

Deliverable D1.2 analyses and assesses the economic impacts of derailments to gain an improved understanding of the nature of economic impacts (composition, types of costs and other types, etc.) and the magnitude and allocation of costs following an incident. This is an important factor to consider and recognise before any derailment detection and mitigation measures are proposed in order to ensure that they are affordable and could be practically adopted by relevant stakeholders. It will further ensure that the solutions to be developed have the potential for market uptake prior to being considered in D-RAIL in later work packages. Solutions proposed need to consider overall cost and charging regimes in relation to the operator, infrastructure provider, rolling stock manufacturer and industry suppliers.

This deliverable provides estimates of average cost for different causes of derailment, and an estimate of indirect costs associated with a generic derailment.

2 Data sources

"Railway accidents and incidents reporting is required in two separate EU legislative acts.

• The Eurostat regulation ((EC) No 2003/91) requires reporting data to Eurostat.

• The Railway Safety Directive (2004/49/EC) requires reporting data to the Railway Agency.

The Railway Safety Directive requires the NSAs to report significant accidents as defined in Regulation (EC) No 2003/91. According to this regulation, the Member States may use national definitions of the indicators during the first five years." [8]

The European Commission has recently (17/11/2012) issued significant regulations which seem to be relevant for D-RAIL project. These two common safety methods (CSMs) have already been published in the Official Journal of the European Union, and shall apply from the 7th June 2013, respectively:

- CSM for supervision (1077/2012), [11], to be applied by National Safety Authorities, and
- CSM for monitoring (1078/2012), [12], to be applied by Railway Undertakings, Infrastructure Managers and Entities in Charge of Maintenance.

It is expected that the above regulations will determine relevant changes in the actual assessment and monitoring systems.

EUROSTAT and ERADIS (the European Railway Agency's database) categorise derailments differently. EUROSTAT records only **significant** accidents, which are defined as accidents either causing fatalities or with total damages amounting to costs of over 150k€.

ERA uses the term **severe** to indicate a derailment with a mechanical impact such that it would have the potential to cause a leakage in a dangerous good wagon. This would be the case, for example, if the wagon were to turn over following the derailment. Derailments have three general categories of severity:

- **'severe'**:
  - **'immediate severe'**: immediately identified as severe
  - **'not immediate severe'**: undetected for some time and potentially end up being classified as severe
- **'not severe'**: detected quickly and the train is brought safely to a stop.

Reporting to ERADIS prior to 2009 was not subject to strict and uniform guidelines and the data is not fully consistent across the range (2005-2010) studied in D-RAIL.

Data about derailments exist both in European and in individual countries' databases. They belong to a number of organisations and are in different formats. Databases differ in structure, reporting criteria, precise definition of causes / categories, etc. Some are public (EUROSTAT, ERADIS, FRA) but most are confidential. The major obstacle in gathering information was confidentiality of data, which means that it is not publicly available and data owners are reluctant to supply it. Other problems we encountered during the work on data gathering and analysis is that most reports and databases do not provide detailed information of derailment cost split into categories, but only total derailment cost. This was mostly just the direct cost of infrastructure and rolling stock, but again in most sources, was not broken down. Even where information of the split of costs was provided, each source had different ways of calculating, naming and dividing costs. Thresholds of reporting accidents also differ between databases.

The present study includes data from Europe, USA and Russia. The study is focussed on the period 2005-2010.

The principal sources of data used for Deliverable D1.2 are:

1. Databases

- European statistics database EUROSTAT
- European safety database ERADIS
- DNV database
- European UIC safety database, includes 20 EU countries
- USA (FRA) safety database
- Russian safety database
- GB Safety Management Information System (SMIS) administered by RSSB
- Safety databases from Austria, France, Germany, Sweden and Switzerland.

2. Studies

- ERA's study "Impact Assessment on the use of Derailment Detection Devices in the EU Railway System", ERA/REP/03-2009/SAF, Date: 07/05/2009. [1] (See Appendix 1)
- DNV study for ERA: "Assessment of freight train derailment risk reduction measures", 2011. [2] (See Appendix 3)
- EU FP6 Project "HEATCO – Developing Harmonised European Approaches for Transport Costing and Project Assessment' Deliverable 5 Proposal for Harmonised Guidelines", 2006. [3]

Two additional relevant studies are:

- "Fatal train accidents on Europe's railways: 1980–2009" A.W. Evans [4]
- EU FP5 Project "ProM@in Influence Diagrams as a modelling tool for LCC analysis of maintenance", 2001. [5] (See Appendix 2)

However, these studies do not provide data suitable for the analysis in this deliverable.

3 Analysis of derailment cost by cause

Data from European countries were gathered during the course of the project. Costs are not available for all derailment incidents, and most cost data for this deliverable were provided from confidential country-specific databases, where data collection and reporting follow country-specific guidelines. Deliverable D1.1 focussed on ranking derailment causes according to the number of derailments with each associated cause, and gave rankings of causes also on a subset of data where the costs were known.

This deliverable focuses on the derailment costs. In this section, the average cost of derailment is estimated for specific derailment causes. In the next section, the breakdown of into direct and indirect costs is estimated. Costs have been brought to 2012-equivalent values using a simple method of adding a 2% annual increase. (2% is approximately the average Euro Area Inflation Rate for the period in question.)

Distribution of total derailment cost from collected derailments in the period 2005-2010 is presented in Figure 3.1. A large number of derailments fall below the threshold of 150k€ threshold for reporting to EUROSTAT. There are a significant number of derailments within the 1-2M€ range, but above that the data become very scattered.

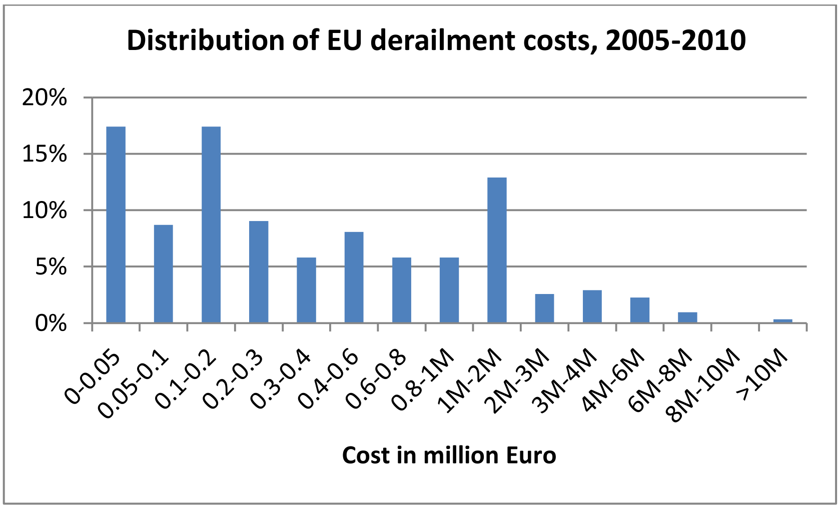

Figure 3.1 Distribution of EU derailment costs 2005-2010. The vertical axis is the number of derailments (expressed as a percentage of the total) where the cost lies within the stated range on the horizontal axis.

Occurrences and costs associated with derailment causes are given in Table 3.1 – Table 3.4.

'Derailment share' is the number of derailments (as a percentage of the total) associated with each derailment cause or category. This is based on the dataset used by DNV (included in the D1.1 database) which is a larger dataset than the dataset used for this deliverable for assessing costs. Unfortunately there are some derailment causes with entries in one dataset but not the other. (There is no estimated derailment share for 'Human factors', 'Other incorrect loading' and 'Wrong setting of points/turnouts'.)

Cost data are from selected European main line derailments from: Austria, France, Germany, Great Britain, Sweden, Switzerland, and other countries (provided by UIC, i.e., Belgium, Bulgaria, Czech Republic, Hungary, Italy, Netherlands, Poland, Slovenia). Time period is 2005-2010. This analysis is not done using the total number of derailments in these countries, but a selection of cases which had information on single cause, cost and year.

Table 3.1 Share of the number of derailments, as a percentage, and average cost per derailment: main categories of derailment causes. (Derailment share and cost per derailment are estimated from different data sets.)

Causes Main category	**Derailment share**	**Cost per derailment**
Weather, Environment and 3rd Party [E]	2%	221,964 €
Infrastructure [I]	34%	624,541 €
Rolling Stock [RS]	38%	1,265,475 €
Operation [O]	23%	403,857 €
Unspecified [U]	4%	541,144 €
Human factor	-	581,671 €

Table 3.2 Share of the number of derailments, as a percentage, and average cost per derailment: infrastructure categories of derailment causes. (Derailment share and cost per derailment are estimated from different data sets.)

Causes DNV Infrastructure Subcategory	**Derailment share**	**Cost per derailment**
Subsidence	0.64%	-
Earth slide/tunnel collapse	0.00%	-
Substructure wash-out due to flooding etc.	0.32%	2,244,532 €
Bridge failure	0.64%	-
Rail failures	2.87%	587,025 €
Joint bar & plug rail failures	0.32%	-
Switch component structural failure	2.23%	114,748 €
Failure of rail support and fastening	2.23%	280,811 €
Track superstructure unsupported by substructure	0.85%	-
Other track and superstructure failure	0.32%	-
Excessive track twist	6.58%	552,627 €
Track height/cant failure	3.40%	281,922 €
Lateral track failure	0.53%	-
Track buckles (sun-curves)	1.59%	626,948 €
Excessive track width	8.60%	474,966 €
Other or unspecified track geometry causes	1.59%	1,155,236 €
Other infrastructure failure	0.96%	122,734 €

Table 3.3 Share of the number of derailments, as a percentage, and average cost per derailment: rolling stock categories of derailment causes. (Derailment share and cost per derailment are estimated from different data sets.)

Causes **DNV Rolling Stock Subcategory**	**Derailment share**	**Cost per derailment**
Hot axle box and axle journal rupture	12.00%	1,282,575 €
Axle shaft rupture	2.55%	265,531 €
Axle rupture, location not known	0.64%	1,057,385 €
Rupture of monoblock wheel	2.55%	1,625,541 €
Failure of composite wheel with rim and tyre	5.41%	2,133,400 €
Excessive flange or wheel tread wear (wrong wheel profile)	2.34%	-
Failure of bogie structure and supports	1.91%	154,061 €
Spring & suspension failure	4.03%	1,865,570 €
Other bogie or suspension failure	1.59%	-
Twisted or broken wagon structure/frame	1.27%	617,741 €
Wagon too high twist stiffness in relation to length	0.21%	88,752 €
Brake component failure	1.91%	346,144 €
Other or unknown rolling stock derailment cause	1.80%	1,079,510 €

Table 3.4 Share of the number of derailments, as a percentage, and average cost per derailment: operations categories of derailment causes. (Derailment share and cost per derailment are estimated from different data sets.)

Causes **DNV Operations Subcategory**	**Derailment share**	**Cost per derailment**
Unfavourable train composition (empties before loaded wagons)	2.23%	357,731 €
Other train composition failure	-	-
Overloading	0.53%	-
Wagon wrongly loaded	2.87%	963,618 €
Wagon partly unloaded	0.96%	-
Insufficient fastening of load	1.59%	657,949 €
Other incorrect loading	-	877,864 €
Speed not according to brake performance	0.32%	-
Brakes not properly checked or tested	2.23%	1,537,430 €
Wrong setting of points/turnouts	-	178,812 €
Wrong setting in relation to movement authority	1.27%	108,946 €
Point switched to new position while point is occupied by train	2.87%	385,098 €
Overspeeding	-	-
Too high speed through turnout in deviated position	-	-
Too high speed elsewhere.	0.96%	-
Other mishandling of train including driver caused SPAD	2.55%	237,821 €
Brake shoe or other object left under train	2.55%	119,431 €
Other operational failure	1.59%	98,450 €

The average costs of derailments were calculated from the tables above as follows:

- If we take an average of all derailments, the average cost per derailment is 802361 €. However, this is significantly skewed by maximum value in the dataset.
- If we look only at derailments in the range 100000 € - 2000000 €, i.e., excluding 'low-cost' derailments and extreme events (these thresholds were selected looking at Figure 3.1), the average cost per derailment is: 608353 €.

Based on the second bullet point above, the value of **600 k**€ as an **average cost of a 'severe' derailment** is suggested for analysis. (A derailment is considered to be 'not severe' if it is detected quickly and the train is brought safely to a stop.)

4 Economic impact assessment of derailments in EU

4.1 Introduction

The methodology of the assessment of derailment costs varies between countries. Most countries provide an assessment of direct costs, i.e., damage to infrastructure and rolling stock, excluding costs from traffic disruption, the environment and so on. This report seeks to identify the cost drivers of derailments, and the significance of different derailment causes for infrastructure, rolling stock, operations and other costs.

In the literature, there are different ways of evaluating the impact of an accident. RSSB Report T357 [9] provides an analysis for a selection of derailments, showing numbers of derailments leading to vehicle damage or turnover, or to structural damage; for derailments at speeds over 30 mph (48 km/h), for example, two thirds cause vehicle damage, and one third cause structural damage. Railways usually report direct costs and estimate indirect costs, but how these are defined varies from country to country. The Heatco report [3] defines it as:

“The direct cost is observable as expenditure today or in the future. This includes medical and rehabilitation cost, legal cost, emergency services and property damage cost. The indirect cost is the lost production capacity to the economy that results from premature death or reduced working capability due to the accident.”

Revision of Annex I of the Safety Directive for the common safety indicators (CSIs), from 2009 [7] in its Chapter 5 (“Common methodologies to calculate the economic impact of accidents”) explains theoretical model that could be used for all accidents. This has been implemented and slightly modified here and some new formulas and suggestions added for use for derailments.

In this study we define the direct cost to be just railway asset costs of infrastructure and rolling stock that are damaged during or after a derailment. For each derailment the total cost can be calculated using the same categories. The following are the typical cost components which should be considered in the impact valuation:

a) Direct infrastructure cost
b) Direct rolling stock and asset costs
c) Human cost in terms of fatalities and injuries
d) Disruption to other services, i.e., passenger and freight (specifically delay minutes)
e) Legal and litigation costs
f) Third party damage i.e. property or business
g) Attendance of emergency services
h) Environment cost – could include: Post-accident clean-up operation; Public dangers (hazardous cargo)
i) Loss of cargo and freight customers.

This study does not include the cost to the economy of decreased or lost production, which is a part of wider societal cost.

4.2 Reference values from ERA cost benefit analysis model

ERA conducted a survey on derailments from NSAs and NIBs [1], and identified the cost of derailments for a number of factors. Reference values and costs are summarised in Table 4.1, and discussed in the following section.

Note: All unit costs reported in the following refer to 2008 price levels.

Table 4.1 Reference values for direct costs from the freight train derailment cost benefit analysis model developed by ERA [1].

	Immediate severe	Not immediate severe	Not severe
Value of Preventing a Fatality (VPF)	1 500 000 €		
Value of Preventing an Injury (VPI)	200 000 €		
Average track damage costs per kilometre (C_{tr})	400 000 €	150 000 €	30 000 €
Average length of track affected (* immediate detection) (L_{tr})	0.5 km	5 km	0.5 km (*) 0.75 km
Average rolling stock damage costs per wagon (C_w)	22 000 € (dangerous goods) 12 000 € (normal freight wagons)		5 000 €
Average number of wagons affected (N_w)	10	10	2.5
Average cost of disruption per hour (C_{hr})	15 000 €	15 000 €	7 500 €
Average number of hours of disruption (N_{hr})	50	50	12
Average environmental cost associated with release of **dangerous goods**.	1 012 384 €		-

4.3 Number, severity and significance of accidents

ERA [1] estimates, for the period 2004-2009, that there are approximately 600 open line freight train derailments each year, and has estimated that about 53% of these are – or have the potential to be – severe. These include those immediately identified as severe as well as those that were not identified as such at the time:

- 33% are immediately identified as severe ('immediate severe'), where:
  - 4% involve dangerous goods
  - 29% do not involve dangerous goods
- 20% are undetected for some time and potentially end up being classified as severe ('not immediate severe'), where:
  - 3% involve dangerous goods
  - 17% do not involve dangerous goods
- 47% are detected quickly and the train is brought safely to a stop ('not severe').

ERA's estimation of the number of derailments per year is based on the number of derailments per year according to EUROSTAT. (EUROSTAT records only **significant** accidents.) These records indicate that there are 500 significant derailments per year, of which about 300 are freight train derailments.

These significant derailments correspond to:

- the 33% 'immediate severe' derailments, and
- 80% of the 20% 'not immediate severe' derailments,

i.e., 49% of derailments are classified as significant and therefore reported to EUROSTAT.

ERA recently adjusted this estimate to **500 open line freight derailments** per year for 2011 [10].

4.3.1 Number of fatalities per year

"Deaths (killed person)" means any person killed immediately or dying within 30 days as a result of an accident, excluding suicides. [7]

On average, based on EUROSTAT, **less than one fatality per year** is caused by freight wagon derailments. (This calculation does not include the disaster at Viareggio in 2009.)

From the UIC safety database, for the five year period 2006 − 2010, 331 derailments of freight trains (taking into account thresholds) were identified, including:

- 1 event with 30 fatalities (Viareggio)
- 3 events with 1 fatality

Viareggio was an extreme event, and including it in the present analysis as a normal event would lead to the conclusion that there are 6.5 fatalities per year. All that can be said is that in derailments involving dangerous goods (which occur in 7% of cases) there is a potential for 30 fatalities.

RSSB's Safety Risk Model (Version v7.2 Freight derailment risk model: HET-13), which is based on approximately 20 years derailment data, estimates there will be 58 freight derailments per year in Great Britain, resulting in 0.39 fatalities. If generalised, this implies there will be 0.0067 fatalities per derailment. If we consider only the estimated 300 **significant** freight derailments each year, the RSSB estimate of 0.0067 fatalities per derailment would predict 2 fatalities each year.

For the purpose of calculation, an assumption of an average of **two fatalities per year** (or 0.004 fatalities per derailment, assuming 500 derailments per year) is justifiable.

Directive 2009/149/EC states:

> *5.1. The **Value of Preventing a Casualty (VPC)** is composed of:*
>
> 1. *Value of safety per se: Willingness to Pay (WTP) values based on stated preference studies carried out in the Member State for which they are applied.*
> 2. *Direct and indirect economic costs: cost values appraised in the Member State, composed of:*
>   - *medical and rehabilitation cost,*
>   - *legal court cost, cost for police, private crash investigations, the emergency service and administrative costs of insurance,*
>   - *production losses: value to society of goods and services that could have been produced by the person if the accident had not occurred.*

Further, economic impact should be calculated as '*number of deaths and serious injuries multiplied by the Value of Preventing a Casualty (VPC),*' but ERA distinguishes between fatalities and serious injuries. The **Value of Preventing a Fatality** (VPF) can be determined by each Member State, but the European recommendation is 1.5 M€ [1].

In summary:

average number of fatalities per year, $n_f = 2$

Value of Preventing a Fatality, VPF = 1.5 M€

annual value of preventing fatalities, $C_{VPF} = n_f \times VPF = 3$ M€

4.3.2 Number of injuries per year

Directive 2009/149/EC states: *"Injuries (seriously injured person)" means any person injured who was hospitalised for more than 24 hours as a result of an accident, excluding attempted suicides." [7]*

From the UIC safety database, for the five year period 2006 − 2010, 331 derailments of freight trains (taking into account thresholds) were identified, including:

- 1 event with 13 serious injuries (Viareggio)
- 9 events with 1 serious injury
- 2 events with 2 serious injuries

RSSB's Safety Risk Model (Version v7.2 Freight derailment risk model: HET-13), which is based on approximately 20 years of derailment data, estimates there will be 58 freight derailments per year in Great Britain, resulting in 1.27 major injuries and 7.37 minor injuries. If generalised, this implies there will be 0.15 injuries per derailment.

From the UIC data, there were 13 serious injuries, not including the additional 13 serious injuries at Viareggio. The RSSB estimate of 0.15 injuries per derailment would predict 49 injuries for the 331 UIC derailments, although only 7 major injuries.

For the purpose of calculation, an assumption of **three serious injuries per year** (or 0.006 serious injuries per derailment, assuming 500 derailments per year) is justifiable.

ERA's recommendation for **Value of Preventing an Injury** (VPI) is 0.2 M€ [1].

In summary:

average number of injuries per year, $n_i = 3$

Value of Preventing an Injury, VPI = 0.2 M€

annual value of preventing injuries, $C_{VPI} = n_i \times VPI = 0.6$ M€

4.3.3 Track Damage

Directive 2009/149/EC states: *"Cost of material damage to* ***rolling stock*** *or* ***infrastructure****" means the cost of providing new rolling stock or infrastructure, with the same functionalities and technical parameters as that damaged beyond repair, and the cost of restoring repairable rolling stock or infrastructure to its state before the accident. Both are to be estimated by Railway Undertakings/Infrastructure Managers on the basis of their experience. Also includes costs related to leasing rolling stock, as a consequence of non availability due to damaged vehicles.*

The approach used by ERA [1] is to specify an average cost per kilometre for track repairs. This cost should include not just the track itself (rails, sleepers, ballast, etc.) but also the supporting infrastructure (catenary poles, signalling, etc.) and other regular features (switches and crossings, electrical installations). The true cost per kilometre will vary widely depending on track type, ground conditions, accessibility, and so on.

Major damage to tunnels, bridges and special structures is rare and should be considered separately, i.e., should not be included in the cost per kilometre, but can be added to the total infrastructure cost if extreme events are being studied.

In summary:

length of track in need of repair [km], L_{tr}

average cost per kilometre, C_{tr}

cost of repairing track, $C_{INF} = L_{tr} \times C_{tr}$

Reference values and costs are given in Table 4.1.

4.3.4 Rolling Stock Damage

Even a minor derailment can cause severe damage to a wagon, and wagons need to be inspected before they can be allowed back on the track, even if only to be towed to the maintenance yard. The damage is especially severe if a wagon turns on its side, or if the poor condition of the vehicle itself was responsible for the derailment. Wagons for transporting dangerous goods are generally more expensive.

The approach used by ERA [1] is to estimate the cost for repairing or possibly replacing one wagon, including additional costs (e.g., towing the derailed vehicle) but excluding costs associated with cargo, and also the average number of wagons that are derailed.

In summary:

number of wagons (per derailment) in need of repair / replacement, N_w

average cost of repair / replacement, C_w

cost of repairing / replacing wagons, $C_{RS} = N_w \times C_w$

Reference values and costs are given in Table 4.1.

4.3.5 Disruption

Directive 2009/149/EC states: *“Cost of delays as a consequence of accidents” means the monetary value of delays incurred by users of rail transport (passengers and freight customers) as a consequence of accidents.*

The directive suggests a method for determining delay costs based on affected traffic and passenger types.

A more generic model of disruption costs is the use estimated ‘delay minutes’. This is an estimation of how much traffic has been delayed by the derailment and the total accumulated delays. This is multiplied by the cost of a ‘delay minute’ (using national data, or the European recommendation of 6000 Euro per hour [5]).

In summary:

number of delay minutes, N_{hr}

average cost of one minute’s delay, C_{hr}

cost of delays, $C_D = N_{hr} \times C_{hr}$

Reference values and costs are given in Table 4.1.

4.3.6 Environmental cost per derailment

Directive 2009/149/EC states: *“Cost of damage to environment” means costs that are to be met by Railway Undertakings/Infrastructure Managers, appraised on the basis of their experience, in order to restore the damaged area to its state before the railway accident.*

Severe derailments involving dangerous goods occur in 7% of derailment cases. A reliable estimate for environmental costs is rare, and the ERA estimate of 1012384 € is for a subset of this 7% where there is a release of dangerous goods.

In ERA’s cost benefit analysis model [1], the minimum value for environmental costs is set at 250 000 €, and this value is suggested here for the environmental costs associate with the 7% of derailments which involve dangerous goods.

In summary:

environmental cost, C_{ENV} = 250 000 €

4.3.7 Cost total

In addition to the above, there are the following four categories of costs individually calculated for each derailment case:

e) Legal and litigation costs
f) Third party damage i.e. property or business
g) Attendance of emergency services
i) Loss of cargo and freight customers.

Labelling the costs associated with these categories as C_{OTHER}, the total cost can be expressed as a sum of all contributing costs as:

$$C_{TOTAL} = C_{VPF} + C_{VPI} + C_{INF} + C_{RS} + C_{D} + C_{ENV} + C_{OTHER}$$

In practice, since there are so many components of cost, and since costs can continue accumulating for some time following the accident, the total cost can be hard to determine. It is useful, therefore, to be able to estimate the total cost based on the direct asset costs by multiplying by a factor *f*:

$$C_{TOTAL} = f * (C_{INF} + C_{RS})$$

The value of the factor *f* is discussed below.

4.4 Division of costs

ERA's estimated costs (see Table 4.2) indicates a 75%/25% split of direct costs (or 80.5%/19.5% if using the revised cost estimates in the DNV model [2] – see Appendix 3 below) between infrastructure and rolling stock. The disruption costs are approximately twice the track damage costs, or alternatively 50% higher than the direct costs. Values used in Table 4.2 calculations are from Table 4.1.

Table 4.2 Direct costs for a single generic derailment, calculated as a weighted average (weighted according to probabilities of different severities and incidence of dangerous goods) using the reference values from ERA's cost benefit analysis.

Derailment category	Weighting	Track	Wagons	Disruption
Immediate severe (DG)	4%	200 000 €	220 000 €	750 000 €
Not immediate severe (DG)	3%	750 000 €	220 000 €	750 000 €
Immediate severe	29%	200 000 €	120 000 €	750 000 €
Not immediate severe	17%	750 000 €	120 000 €	750 000 €
Not severe	47%	20 000 €	12 500 €	90 000 €
Total Costs (Weighted)		**225 400 €**	**76 475 €**	**439 800 €**
as percentage of Track + Wagons		*75%*	*25%*	*146%*

Unfortunately, the cost data are confidential and the countries cannot be named, that is why we are using terms Country 1, etc., and using % split and not actual costs in EURO.

From the analysis of Country 1 derailment data in D-RAIL, the distribution of direct costs of derailments between infrastructure and rolling stock is given in Table 4.3. The rolling stock cost share is less than 20%. Most of the infrastructure cost is superstructure cost.

Table 4.3 Share of costs, Country 1 data

Derailments **Direct cost breakdown**		**Infrastructure cost** **Breakdown into subcategories**	
Total	**100%**		
Infrastructure	82%	**Infrastructure total**	**100%**
		Superstructure	93%
		Operation company - Infra Services	3%
		Signalling	2%
		Operational costs	2%
Rolling stock	14%		
Unknown	4%		

Country 3 has a different split of costs from Country 1. From the analysis of Country 3 derailment data in D-RAIL, see distribution of direct costs of derailments in Table 4.4, infrastructure has 76% and rolling stock has 12%. Most of the infrastructure cost is structural works (67%).

Table 4.4 Share of costs, Country 3

Derailments Cost breakdown	Breakdown into subcategories	
Structural works	Track / sub structure	67%
	Bridge	0%
Signalling / communication systems	Switch/ track lock	3%
	other	1%
Mechanical and electrical system	catenary	3%
	safety installation railroad crossing	0%
	other	2%
Follow-up costs	clearance and recovery	2%
	rail replacement service	0%
	non-availability	3%
	loss of income	0%
	additional stuff	0%
Property damage of third party	other	6%
Vehicle	freight car	6%
	passenger car	4%
	motor vehicle	2%
Environment	substructure	0%
Total cost		**100%**

From the analysis of the cost-impact data from the five European countries selected for this study, the split of direct costs is compiled in Table 4.5. On average, the split between direct costs is: infrastructure 78%, rolling stock 22%. This is in agreement with the estimates based on ERA data (75%/25%) and DNV (80%/20%). For future analysis work, a split of infrastructure / rolling stock as 80%/20% is suggested.

Table 4.5 Split of derailment direct costs

Country	Infrastructure	Rolling stock
1	85	15
2	50	50
3	86	14
4	83	17
5	86	14
Average	78	22

Indirect costs were not well-documented so conclusions of their share in the total cost cannot be made with certainty. From D-RAIL database of derailments it was seen that indirect costs are 33% on top of direct costs, but from ERA's previous study this looks low.

4.5 Summary of derailment costing in EU

The data collected in D-RAIL indicates an 80%/20% split of direct costs between infrastructure and rolling stock. Disruption cost (delay minutes, etc.) is difficult to estimate and ranges from only 15% of the direct cost in one data set, to 150% based on ERA's cost benefit analysis model. The disagreement may result from what costs are included in the disruption cost.

ERA's analysis of derailments (summarised in section 4.4) has led to an estimate of 500 open line freight derailments per year.

Based on the estimates above, a number of conclusions can be made for modelling derailment costs:

- There are 2 fatalities per year and 3 serious injuries per year, at costs of 1.5M€ per fatality and 0.2M€ per serious injury, so the human cost is 3.6M€ per year (see sections 4.3.1 and 4.3.2). (On average, the freight railway network sees 385104 million tonne-km per year; the associated human cost is therefore 9.35€ per million tonne-km.)
- Assuming 500 derailments per year, there are 0.004 fatalities and 0.006 serious injuries per derailment, this is equivalent to a human cost of 7200€ per derailment.
- Environmental clean-up costs (see section 4.3.6) are negligible except in the 7% of derailments involving dangerous goods. (Assuming 500 derailments per year, there are 35 derailments each year involving dangerous goods.) If the minimum cost of environmental clean-up per dangerous goods derailment (250000€) is assumed here, this is equivalent to 17500€ (35*250000€/500=17500€) per derailment. (The associated environmental cost is therefore 27.3€ per million tonne-km.)

The human cost and environmental cost are independent of the type of derailment, and add a fixed cost of 23500€ per derailment. However, this is an average value, and could be thought of as, for example, seven severe derailments per year, each incurring costs of 2M€ (rather than 600 derailments per year, each incurring the cost of 23500€ per derailment).

5 Impact assessment of derailments in the USA

5.1 USA analysis of distribution of derailment costs

In the USA, the distribution of derailment costs differs from what is reported in Europe. Of the approximately $240 million a year of reported derailment costs (which includes only Track damage and Equipment damage), approximately 65% of the cost is equipment damage (to include wagons and locomotives) and 35% is track (which includes track, structures and signal damage and repair costs). This is presented in Table 5.1. These numbers are based on derailment data as reported to the US Federal Railroad Administration (FRA). All derailment above the reporting threshold of $9,200 (approximately 7000 Euros) must be reported, but reported damage only includes equipment and track costs. Other cost of derailments, to include loss of lading (commodity), cost of train delays and rerouting, etc. are estimated by the Association of American Railroads to be an addition 80 to 100% of the track and equipment costs (thus representing a multiplier of 1.8 to 2.0 times the reported track and equipment costs).

Table 5.1 Spread of costs of derailments between infrastructure ('track') and equipment per year, USA data 2005-2010.

Year	Equipment Damage	Track Damage	Total	Equipment Damage	Track Damage	Total
	Dollar	**Dollar**	**Dollar**	**Percentage**	**Percentage**	**Percentage**
2005	$148,843,645	$98,855,255	$247,698,900	60.09%	39.91%	100%
2006	$163,904,306	$100,418,026	$264,322,332	62.01%	37.99%	100%
2007	$170,234,768	$89,835,851	$260,070,619	65.46%	34.54%	100%
2008	$152,444,708	$83,255,669	$235,700,377	64.68%	35.32%	100%
2009	$160,473,251	$70,046,785	$230,520,036	69.61%	30.39%	100%
2010	$140,083,859	$72,956,630	$213,040,489	65.75%	34.25%	100%
Average	**$155,997,423**	**$85,894,703**	**$241,892,126**	**64.5%**	**35.5%**	**100.0%**
Total	**$935,984,537**	**$515,368,216**	**$1,451,352,753**			

The following is an excerpt from the FRA manual for reporting derailments that deals with costs.

5.1.1 Equipment damage

The agency that is preparing the report should enter the amount of damage sustained by the equipment.

The current method used to calculate material costs, i.e., depreciated value estimates, will continue to be used by all railways. If a railway chooses to use parts from older equipment to repair a damaged car from an accident, then fair market value for the old part should be used and documented as to fair market value (documentation should be publicly available source for refurbished equipment). FRA is concerned that the railway pay special attention to using refurbished parts that might affect safety.

5.1.2 Labour costs

When estimating damage costs, the labour costs to be reported are only the direct labour costs to the railway, e.g., hourly wages, transportation costs, and hotel expenses. The cost of fringe benefits is excluded when calculating direct labour costs. Overhead is also excluded when calculating damage costs due to the unacceptable, non-uniform treatment of overhead under the current process. If the railway chooses to have employees work overtime, then the overtime direct labour charges must be used.

For services performed by a contractor, a direct hourly labour cost is calculated by multiplying the contractor's total labour hours charged to the railway by the applicable direct hourly wage rate for a railway worker in that particular craft. However, if a railway cannot match the equivalent craft to the labour hours spent by a contractor, then the railway must use the loaded rate, i.e., the cost by hour for labour, fringe benefits, and other costs and fees for services charged by the contractor for the tasks associated with the repair of the track, equipment, and structures due to the train accident.

5.1.3 Track, signal, way & structure damage

Reportable damage includes labour costs[1] and all other costs to repair or replace in kind damaged on-track equipment, signals, track, track structures, or roadbed. Reportable damage does not include the cost of clearing a wreck, damaged lading, or environmental clean-up costs, etc.

The railway responsible for maintaining the track on which the accident/incident occurred will enter the cost of damages to the track, signals, roadbed, track structures, etc. If a railway uses rail salvaged from an abandoned track or track no longer in use, then the cost of the rail and ties salvaged are zero; however, the direct labour costs for salvaging the rail and ties, building the panels, and replacing the rail (including subsequent welding costs if continuously welded rail is used) must be employed in calculating the costs of the accident.

5.2 USA case studies

Several examples of specific reported derailments are presented as follows:

Union Pacific railway derailment of a freight train near Elkhorn, Nebraska, on 1 October 2009.

Eight wagons in a 134 wagon train (two locomotives) derailed on main track. Cause of derailment was an overheated axle bearing. Reported equipment damage (cost of repair or scrapping of eight wagons) was $511,485. Reported track damage was $273,347. Total reported damage was $784,832. Equipment costs represented 65%, track costs 35%.

CSX Transportation derailment of a freight train near Linton, Indiana, on 4 July 2010.

Six wagons in a 53 wagon train (two locomotives) derailed at a switch. Cause of derailment was a broken switch point. Reported equipment damage (cost of repair or scrapping of 6 wagons) was $100,000. Reported track damage was $50,000. Total reported damage was $150,000. Equipment costs represented 67%, track costs 33%.

BNSF Railway derailment of a freight train near Miles City, Montana, on 14 December 2010.

Five wagons in a 123 wagon train (two locomotives) derailed at a switch. Cause of derailment was a worn switch point. Reported equipment damage (cost of repair or scrapping of 5 wagons) was $84,000. Reported track damage was $23,700. Total reported damage was $107,700. Equipment costs represented 78%, track costs 22%.

[1] Labour overheads are not included unless a contractor is used in which case all of the direct costs are reported including overheads.

6 Conclusions

Most European databases do not provide detailed information of derailment cost split into categories, but only the total derailment costs. Even where there is information of the split of costs, each source has a different way of calculating, naming and dividing the costs. This presented a major obstacle in making a correct economical assessment of derailment impact.

We created a theoretical model for economical assessment of derailments in Europe. From collected data and information from the literature, we tried to estimate actual values for derailment costs. We re-evaluated findings from D1.1 about causes of derailments, using new data from Germany, Switzerland and Sweden.

Rolling stock is the assigned cause for about 38% of derailments, which corresponds to over 50% of total derailment costs.

Railways nowadays are split, and infrastructure and vehicle owners often belong to different companies. Further, maintenance is also often separate. It would therefore be interesting to find a mechanism of enforcing better maintenance and monitoring of rolling stock.

The data collected in D-RAIL indicates an 80%/20% split of direct costs between infrastructure and rolling stock. Disruption cost (delay minutes, etc.) is difficult to estimate and ranges from only 15% of the direct cost in one data set, to 150% based on ERA's cost benefit analysis model. Reasonable practice would be to assume that the indirect costs, if unknown, are equal to the direct costs.

The average cost of a severe derailment is estimated as 600000€. The human cost and environmental cost are independent of the type of derailment, equivalent, on average, to 24700€ per derailment, assuming 500 open line freight derailments per year.

7 Recommendations

- Same reporting system for all EU countries to a unique EU safety database

  Explanation: At the moment we have in EU 3 databases on European level: EUROSTATS, ERADIS and UIC databases. This new safety database should have levels of confidentiality embedded. Each country would be responsible for its own data update. Thresholds for reporting accidents, formulas, lists and categories should be the same for all countries. However, thresholds based purely on cost may create an impression of higher numbers of derailments in countries where costs are generally higher; thresholds may therefore need to be scaled according to the price level indices for the Member States.

  A manual should be provided for reporting derailments that deals with costs and prescribes how to calculate them in detail to avoid ambiguity. The model presented in this report can be used as a basis for the calculation. For example, infrastructure costs should include categories such as: track, substructure, bridge, tunnel, signalling, labour cost for repair, etc.

- Further research is required for studying (and preventing) derailments caused by ‘human factors’.

  Explanation: Human factors are the cause of a high proportion of accidents. The further understanding of the main HF issues in derailment events is key for supporting the identification of suitable and proportionate mitigation measures.

- Improved infrastructure and rolling stock maintenance.

  Explanation: Poor maintenance is underlying cause in many derailments. It is the responsibility of infrastructure and vehicle owners to ensure minimum quality of their assets required by regulations. Independent periodic inspection is advised to ensure this.

- D-RAIL should mainly focus on long term mitigation measures.

  Explanation: Preliminary work done in WP4 along with data analysed by ERA [10] show that most short and medium term mitigation measures have low effect on reducing the economic impact of derailments and therefore D-RAIL should mainly focus on long term mitigation measures, but also try to provide selection methodology of the most efficient short and medium term ones.

References

1. ERA's study "Impact Assessment on the use of Derailment Detection Devices in the EU Railway System", RA/REP/03-2009/SAF, Date :07 / 05 / 2009
2. DNV study for ERA: "Assessment of freight train derailment risk reduction measures", 2011.
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5. EU FP5 Project "ProM@in Influence Diagrams as a modelling tool for LCC analysis of maintenance", 2001.
6. Directive 2004/49/EC of the European Parliament and of the Council of 29 April 2004. (Railway Safety Directive)
7. COMMISSION DIRECTIVE 2009/149/EC of 27 November 2009 amending Directive 2004/49/EC of the European Parliament and of the Council as regards Common Safety Indicators and common methods to calculate accident costs
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9. RSSB T357 "Cost-effective reduction of derailment risk: Initial data analysis" (2006)
10. ERA "Prevention and mitigation of freight train derailments at short and medium terms, 2012.
11. COMMISSION REGULATION (EU) No 1077/2012 of 16 November 2012 on a common safety method for supervision by national safety authorities after issuing a safety certificate or safety authorisation.
12. COMMISSION REGULATION (EU) No 1078/2012 of 16 November 2012 on a common safety method for monitoring to be applied by railway undertakings, infrastructure managers after receiving a safety certificate or safety authorisation and by entities in charge of maintenance.

Appendices

Appendix 1 ERA DDD study

Impact Assessment on the use of Derailment Detection Devices in the EU Railway System ERA/REP/03-2009/SAF

Date :07 / 05 / 2009

Document type: Public

- Cost figures, please see sections 5.2.2.4 and 8.2.
- Definition of accident severity, please see section 5.2.2.3.

Tables

"As a result of the analysis of the reported data it was concluded that rough average damages to the railways system could be estimated as follows for the different derailment categories:

Accidents category	**Average damages to tracks**		**Average damages to rolling stocks**		**Average damages to operation**	
	Average Km	Average cost (€/km)	Average # wagons	Average cost/wagon (€/wagon)	Average hours of disruption	Average cost/hour (€/hour)
Immediate severe derailment of DG wagons (SD1)	0,5	400000	10	22000	50	15000
Delayed severe derailment of DG wagons (SD2)	5	150000	10	22000	50	15000
Immediate severe derailment of normal freight wagons (SD3)	0,5	400000	10	12000	50	15000
Delayed severe derailment of normal freight wagons (SD4)	5	150000	10	12000	50	15000
Non severe derailment of DG or normal freight wagons (NSD1) immediately detected	0,5	30000	2,5	5000	12	7500
Non severe derailment of DG or normal freight wagons (NSD2)	0,75	30000	2,5	5000	12	7500

These values were used as reference values in the study. For the sensitivity analysis, minimum and maximum benefit values were also used, these are shown in annex 5."

8.2 Core assumptions for the CBA

Applied values for life time and discount factor
The NPVs are calculated for three life time values, 10, 40 and 60 years, using in all three cases a discount factor of 4%. Our central value for life time is 40 years, while the 10 year and 60 year values are used to provide information about NPV for a short and long time horizon. The 10 year life time value may be particularly relevant for industry where short term economic feasibility may be important with a longer time horizon would be considered too uncertain.
In the following the core assumptions regarding unit costs values are presented for the following items:

- Value for Preventing a Fatality
- Value for Preventing an Injury
- Track damage costs per km
- Rolling stock damage costs per wagon
- Operation disruption costs per hour of incident
- Environmental costs per derailment

All unit costs reported in the following refer to 2008 price levels (prior to the current worldwide economic recession).

Value for Preventing a Fatality (VPF)

Monetary values per avoided fatalities are available **on European basis** from the HEATCO project as used as part of the revision of Annex I of the Safety Directive for the common safety indicators (CSIs). Web-link to HEATCO: http://heatco.ier.uni-stuttgart.de/

Minimum (€)	Reference (€)	Maximum (€)
1 500 000	1 500 000	1 500 000

Value for Preventing an Injury (VPI)

Monetary values per avoided injuries are available **on European basis** from the HEATCO project as used as part of the revision of Annex I of the Safety Directive for the common safety indicators (CSIs). Web-link to HEATCO: http://heatco.ier.uni-stuttgart.de/

Minimum (€)	Reference (€)	Maximum (€)
200 000	200 000	200 000

Track damage costs per km

Track damage costs per km are estimated from the consultation (see above) of the NIBs and NSAs on past derailment accidents. The unit costs (reference values) are highest for track damage to be repaired in case of immediate severe derailment and lowest for track damage to be repaired in case of non severe derailment detected by the DDD, staff or other means.

	Minimum (€)	Reference (€)	Maximum (€)
Track damage to be repaired in case of immediate severe derailment	400 000	400 000	400 000
Track damage to be repaired in case of non immediate severe derailment	100 000	150 000	200 000
Track damage to be repaired in case of non severe derailment detected by the DDD	30 000	30 000	30 000
Track damage to be repaired in case of non severe derailment detected by staff or other means	30 000	30 000	30 000

Rolling stock damage per wagon

The costs of wagon replacement / repair have been estimated from the data communicated by VTG-Rail as well as the NIB / NSA Derailment survey. Higher replacement / repair costs are assumed for severe derailment than non-severe derailment.

	Minimum (€)	Reference (€)	Maximum (€)
Rolling stock damage to be replaced or repaired in case of severe derailment	16 000	22 000	30 000
Rolling stock damage to be replaced or repaired in case of severe derailment (without dangerous goods wagons involved)	8 000	12 000	15 000
Rolling stock to be replaced or repaired in case of non severe derailment (detected by DDD)	5 000	5 000	5 000
Rolling stock damage to be repaired in case of non severe derailment (detected by staff or other means)	5 000	5 000	5 000

Operation disruption costs per hour of incident

Unit values for disruption costs per hour of incident are fixed according to the following table. The values have been estimated using HEATCO values of time (adjusted upwards as transport users value higher the time for delays / waiting compared to normal travel time).

Information from the UK RAIB (Rail Accident Investigation Board) and other UK sources about delay minutes for a sample of derailments have been used to determine how many trains will be affected during a 1 hour of an incident.

	Minimum (€)	Reference (€)	Maximum (€)
Operation disruption in case of severe derailment	10 000	15 000	20 000
Operation disruption in case of non severe derailment	7 500	7 500	7 500

Environmental costs per derailment

The typical environmental costs per derailment have been estimated from the consultation of the NIBs and NSAs on past derailment accidents.

	Minimum (€)	Reference (€)	Maximum (€)
Average environmental costs for severe derailments involving dangerous substances	250 000	1 012 384	2 116 552

Appendix 2 EU FP5 Project ProM@in

Derailment costs vary widely, but the EU FP5 Project ProM@in presented a breakdown of derailment costs for use in life cycle costing as shown below:

Interest rate	0.08
Number of years	15
Expected fatalities per derailment	0.2
Expected injuries per derailment	0.2
"Value" of life	2,500,000
"Value" of injury	250,000
Material cost of derailment	1,600,000
Cost of fixing one rail	5,000
Investment cost, one detector	250,000
Annual operating cost one detector	6,000
Average clearance time, derailment	720
Delay cost per minute	100
d(m,k)	0.12

Breakdown of derailment costs for use in LCC analysis (All costs in Euro €) [Jørn Vatn, Influence Diagrams as a modelling tool for LCC analysis of maintenance, EU FP5 Project ProM@in (Findings & Conclusions)]

Appendix 3 DNV reports

Assessment of freight train derailment risk reduction measures:
B2 – Risk model and potential effectiveness of measures
Report for European Railway Agency
Report No: BA000777/07
Rev: 02
21 July 2011

"6.2.1 Normal Freight Human Fatalities and Injuries

When a normal freight vehicle derails there could also be a number of human fatalities or injuries if the freight train collides with a passenger train.

From our accident analysis we note only one case where injuries have been recorded, and in this case the number of injuries recorded was 2.

The number of injuries from normal freight derailments is calculated one in 10 accidents. This is a conservative assumption as our accident database indicates something less than this.

These values are used, with an associated cost per injury, as previously used by the Agency.

Concerning fatalities, it is very rare for these to occur from the mechanical impact associated with a freight train derailment. In the accidents we have studied (see Section 3.2) there have been none reported over a 10 year period. We note that the Agency used an estimate of one per year, however this would seem pessimistic based on available data.

Eurostat (table rail_ac_catvictin) records zero 3rd party fatalities associated with train derailments (with the exception of Viareggio) in the period 2006 to 2009 and 6 railway employee fatalities in the same period the (for the EU-27) although Eurostat includes both passenger and freight train derailments. For freight train derailments there are fewer railway employees at risk (usually the driver only), and we also note that it is unusual for the locomotive be directly involved.

These data lead us towards a fatality figure, resulting from the mechanical impact of a freight train derailment, as significantly less than one per year and for the purposes of our assessment we have selected a value of 0.2 fatalities per year.

6.2.2 Freight Train Derailment Railway System and Operational Disruption

When a freight train derailment occurs there will be additional impacts on the railway system and operations. The following parameters were used relating to the costs associated with these impacts.

Table 14 Railway System and Operational Costs

	Track Damage		Wagon Damage		Disruption Costs	
Scenario	Average Km	Cost (E/km)	# wagons	Cost/wagon (E/wagon)	Hours disruption	Cost/hour (E/hour)
Immediate severe, DG involvement	0.5	427746	7	23526	50	16040
Not immediate severe, DG involvement	5	160405	7	23526	50	16040
Immediate severe, no DG involvement	0.5	427746	7	12832	50	16040
Not immediate severe, no DG involvement	5	160405	7	12832	50	16040
Not severe derailment, safe stop	0.5	32081	2	5347	12	8020

6.3 Impact Model Usage, Summary and Outputs

We report above the development of our impact models. Using the model, with the parameters described, the following results are obtained (for the case of 500 derailments per year):

- Total cost of freight train derailments = Euro 505 million. (This may vary between Euro 195 million and Euro 701 million using minimum and maximum values in Table 14.)

- Average cost per freight train derailment = Euro 1.01 million. (Ranging between Euro 390,000 and Euro 1,402,000 using minimum and maximum values in Table 14).
- Number of fatalities = 3.9 (resulting mainly from incidents in which there is a release of DG).
- Major cost impact relates to operational disruption.

As a comparison, our database has recorded 2 accidents with loss of life and these are associated with incidents in which there is a release of DG. These equate to a total loss of life of 34 over a 10 year period. This is consistent with our modelling.

The principal future use of our impact model is the calculation of benefits that may be achieved through the implementation of new measures."