Economic Impact of Freight Train Derailments in the Perspective of Demands and Operational Framework to 2050

Seminar on Reduction of Derailment in Europe
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SEVENTH FRAMEWORK PROGRAMME

OUTLINE

- Objective
- Methodology
- Literature Review
- Top-down approach
  - Methodology
  - Results
- Bottom-up approach
  - Methodology
  - Results
- Findings

OBJECTIVES

- Safe and reliable traffic management is very essential for European railway systems;
- Derailment causes fatalities/injuries, track/rolling stock damage, disruption of services, loss of cargo and customers etc.
- Studying causes of derailments and associated impacts including
  - Economic,
  - Financial and
  - Social costs;
- Studying the interventions and/or mitigation techniques available to prevent derailments;
- Conduct cost benefit analysis:
  - Costs - for the prevention and/or mitigation measures;
  - Benefits - how much money could be saved by reducing the occurrence of derailments;
- Find out a suitable mitigation technique(s) for European railways up to year 2050.

METHODOLOGY

- Data collection on derailments from different sources;
- Classification and ranking of the causes of derailments;
- Review of existing studies on impact of derailment;
- Identification of suitable mitigation techniques;
- Top-down approach -
  - Analysis and assess the impact and effectiveness of interventions or mitigation techniques;
- Bottom-up approach - estimate costs and benefits based on a set of interventions;
- Combine the results of the two approaches;
- Find out - which set(s) of interventions are feasible or best.

LITERATURE REVIEWS

- At the time of the research, there were a limited number of studies on the subject at the European level
- DNV (2011) study - Assessment of freight train derailment risk reduction measures;
- ERA (2009) Impact assessment for the Derailment Detection Devices (DDDs)
- UK ORR (2008) Internal guidance on Cost Benefit Analysis (CBA) in support of safety-related investment decisions;
- European Commission (2008) Guide to Cost Benefit Analysis of Investment Projects, DG of Regional Policy

LITERATURE REVIEWS CONT'D

- The DNV (2011) study combines the cost analysis of both preventative and mitigating techniques and measures;
  - The study suggests that only Wheel Impact Detectors demonstrated a significant BC ratio (more than 4 in y40) and roller cages (around 3 in y40);
- The ERA (2009) study focuses on Derailment Detection Devices;
  - The study suggests that the investment on Derailment Detection Devices is not financially justified with regard to human risks;
- Both studies
  - Strong focus on preventative measures;
- The current study focused on CB Analysis for mitigation techniques

DERAILMENT ACCIDENT DATA COLLECTION

DATA SOURCES

Austria, GB, France, Germany, Sweden, Switzerland,

- Infrastructure stakeholders
- European Rail Agency
- Incident reports and enquiries
- DNV Study
- UIC safety database
- Non-European sources (USA and Russia)

→ **D-Rail**
Database of accidents

Information in D-Rail database:

- **Number of derailments**
- **Causes**
- **Costs**

(six-year period: 01/01/2005 – 31/12/2010)

DATABASE FORMAT - CAUSES

Each database has a different format, criteria for which data is collected and classification of causes. In order to provide a comprehensive review, analysis and comparison we tried to organise the data into the same format. DNV classification was used as a basis, with some slight modifications.

Infrastructure failures and defects

1. Failed substructure, comprising:
a. Subsidence
b. Earth slide / tunnel collapse (leading to derailment, not collision)
c. Substructure wash-out due to flooding etc
d. Bridge failure (leading to derailment)
2. Structural failure of the track superstructure, comprising:
a. Rail failures
b. Joint bar & plug rail failures
c. Switch component structural failure
d. Failure of rail support and fastening
e. Track superstructure unsupported by substructure
f. Other track and superstructure failure
3. Track geometry failure, comprising:
a. Excessive track twist
b. Track height/cant failure
c. Lateral track failure
d. Track buckles (heat-curves)
e. Excessive track width
f. Other or unspecified track geometry causes
4. Other infrastructure failures

Rolling Stock failures and defects

1. **Wheel-set failures (wheels and axles), comprising:**
a. Axle ruptures:
i. Hot axle box and axle journal rupture
ii. Axle shaft rupture
iii. Axle rupture, location not known
b. Wheel failure:
i. Rupture of monoblock wheel
ii. Failure of composite wheel with rim and tyre
iii. Excessive flange or wheel tread wear (wrong wheel profile)
2. **Bogie and suspension failures, comprising:**
a. Failure of bogie structure and supports
b. Spring & suspension failure
c. Other
3. **Twisted or broken wagon structure/frame**
4. **Wagon with too high twist stiffness in relation to length**
5. **Brake component failure**
6. **Other or unknown rolling stock derailment cause**

Operation failures and defects

1. **Train composition failures, comprising:**
a. Unfavourable train composition (empties before loaded wagons)
b. Other
2. **Improper loading of wagon, comprising:**
a. Overloading
b. Skew loading
i. Wagon wrongly loaded
ii. Wagon partly unloaded
c. Insufficient fastening of load
d. Other incorrect loading
3. **Train check and brake testing, comprising:**
a. Un-suitable brake performance for route characteristics
b. Brakes not properly checked or tested
c. Brakes not correct set with respect to load or speed of brake application
4. **Wrong setting of points/turnouts, comprising:**
a. Wrong setting in relation to movement authority
b. Point switched to new position while point is occupied by train
5. **Mishandling of train en route, comprising:**
a. Speeding:
i. Excessive speed through turnout in deviated position
ii. Excessive speed elsewhere
b. Other mishandling of train
6. **Brake shoe or other object left under train**
7. **Human factors**
8. **Other operational failures**

DERAILMENT RANKING

Mainline derailments for Europe (source DNV data set) were categorised (per number) into the following **groups:**

1. Derailments caused by *Infrastructure failures*	***34%***
2. Derailments caused by *Rolling Stock failures*	***38%***
3. Derailments caused by *Operation failures*	***22%***
4. Derailments caused by *Weather, Environment and 3rd Party*	***2%***
5. *Unspecified*	***4%***

96% of derailments were successfully categorised into one of these four groups. The spread between countries is sometimes huge due to differences in operation, track, rolling stock, and also in categorisation criteria.

The ranking of major causes in DNV study

1. hot axle box and axle journal rupture
2. excessive track width
3. excessive track twist
4. failure of composite wheel with rim and tyre
5. spring & suspension failure
6. track height/cant failure
7. rail failures
8. wagon wrongly loaded
9. point switched to new position while point is occupied by train
10. axle shaft rupture
11. rupture of monoblock wheel
12. other mishandling of train including driver caused SPAD
13. brake shoe or other object left under train
14. wrong wheel profile
15. switch component structural failure
16. failure of rail support and fastening

The ranking of major causes in Europe

1. Hot axle box and axle journal rupture
2. Excessive track width
3. Wheel failure
4. Skew loading
5. Excessive track twist
6. Track height/cant failure
7. Rail failures
8. Spring & suspension failure

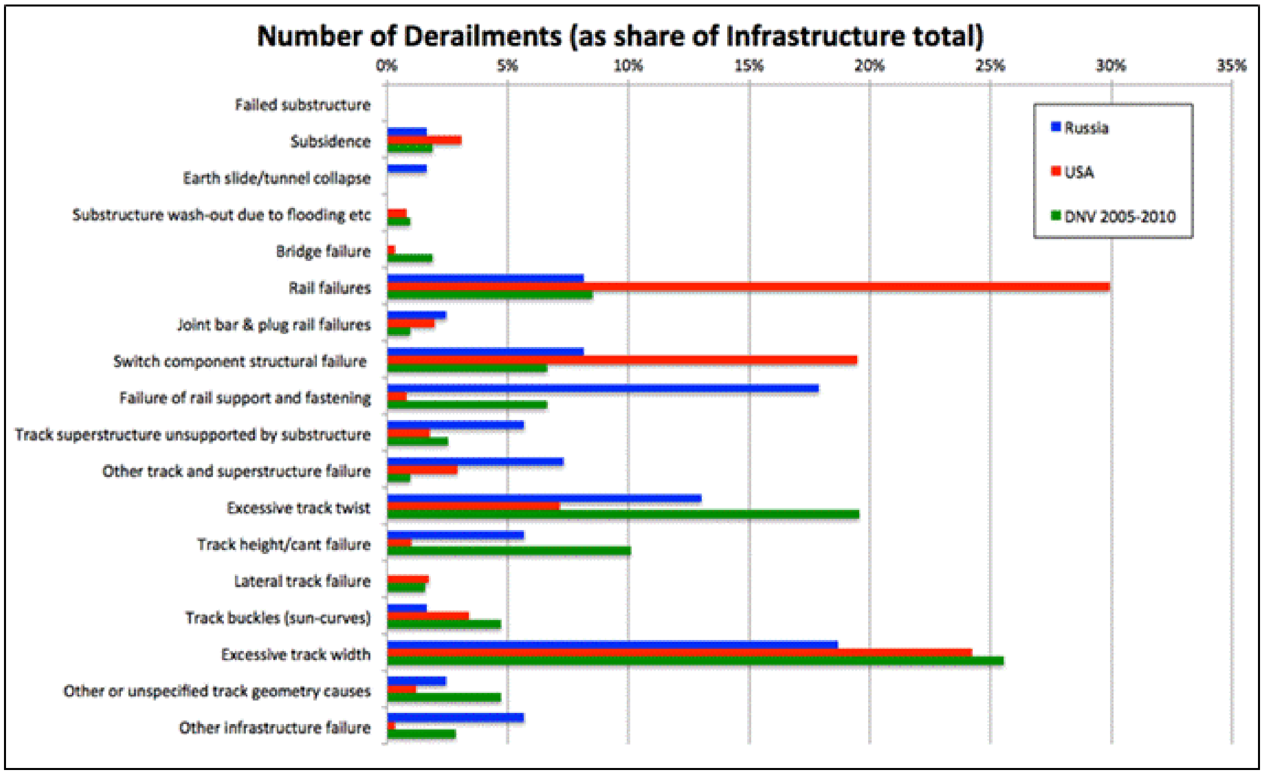
The ranking of major causes in the world

1. [I] rail failures
2. [RS] failure of bogie structure and supports
3. [I] excessive track width
4. [RS] hot axle box and axle journal rupture
5. [I] excessive track twist
6. [I] switch component structural failure
7. [O] wrong setting in relation to movement authority (turnouts)
8. [I] track height / cant failure
9. [O] wagon wrongly loaded
10. [O] other object under the train
11. [O] human and operational factor
12. [I] failure of rail support and fastening
13. [RS] failure or rupture of wheel & axles
14. [RS] twisted or broken wagon structure/frame
15. [RS] spring and suspension failure
16. [O] speeding

DERAILMENTS' CAUSES

Infrastructure causes

(based on the number of derailments)



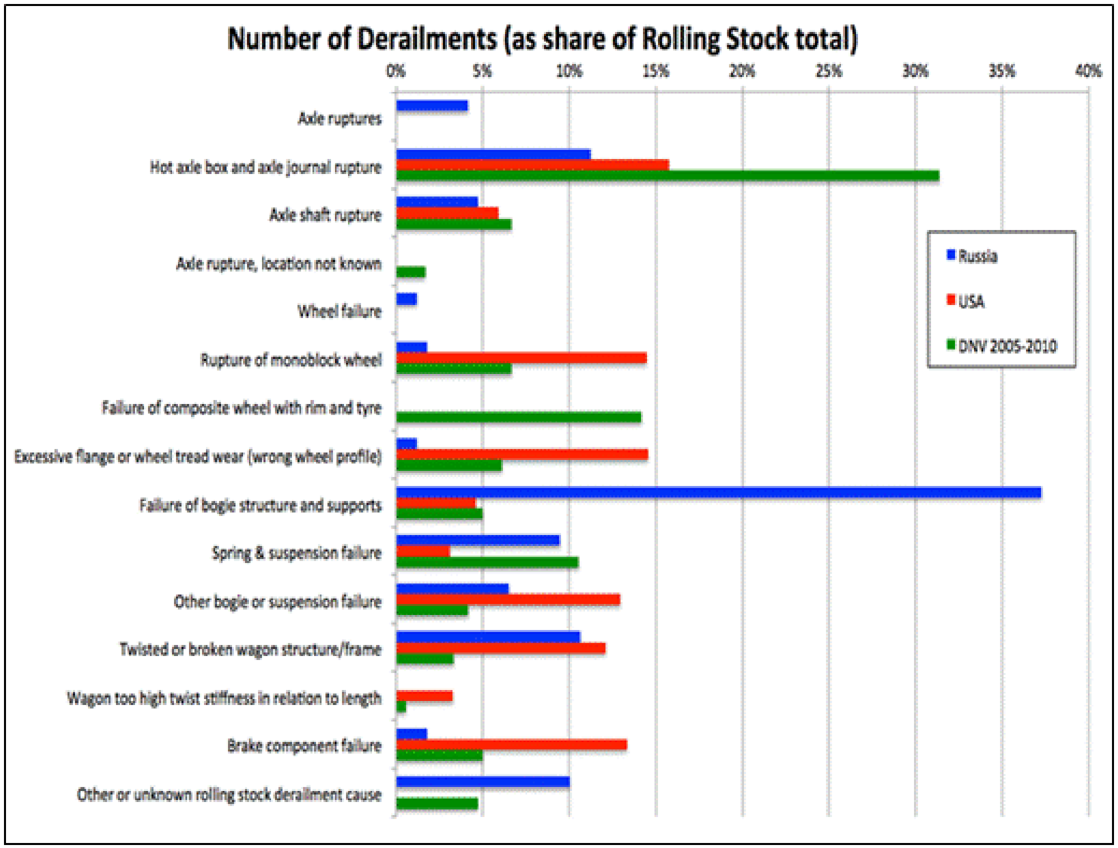
Top categories:

1. excessive track width
2. track height / cant failure
3. rail failures
4. excessive track twist
5. track superstructure unsupported by substructure
6. switch component structural failure

DERAILMENTS' CAUSES

Rolling stock causes

(based on the number of derailments)

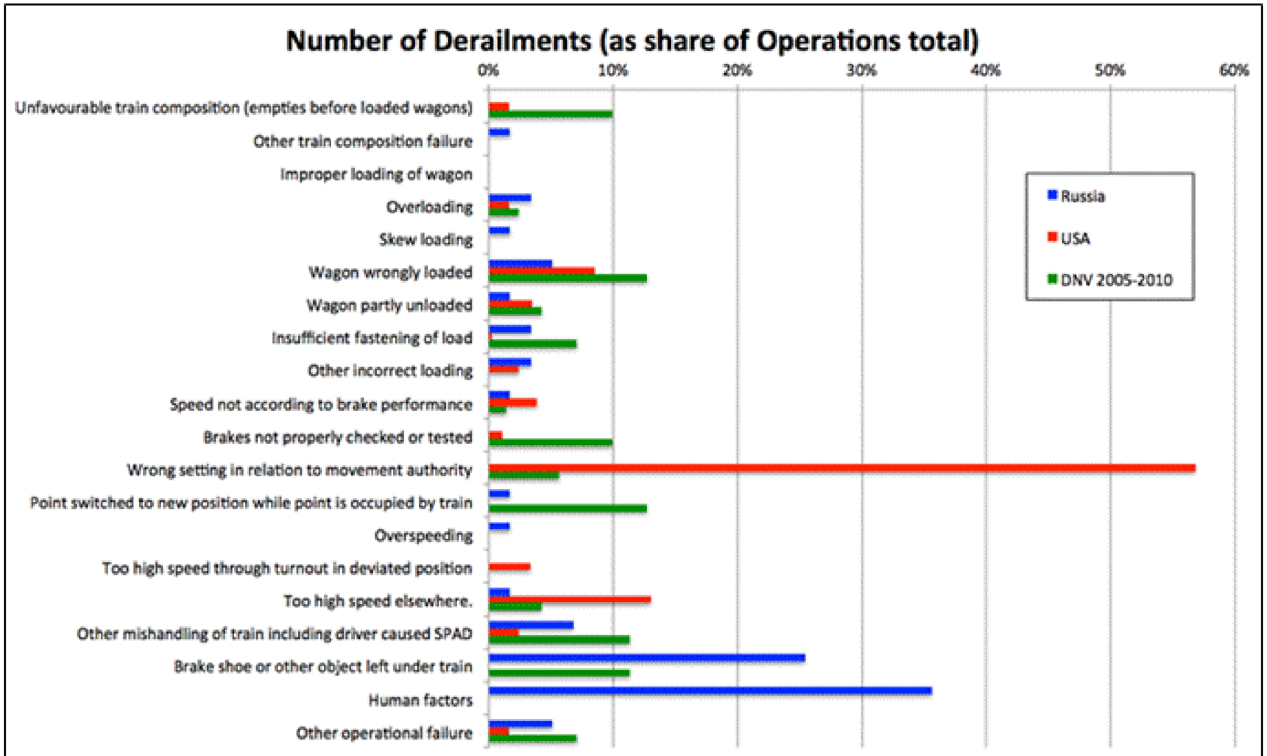


Top categories:

1. hot axle box and axle journal rupture
2. wheel break and failure
3. spring and suspension failure
4. axle break and failure
5. brake failure

Operational causes

(based on the number of derailments)



Top categories:

1. Human and organisational factors
2. Wrongly loaded wagon
3. Point switched to wrong position
4. Other mishandling of train including driver caused SPAD
5. Brake shoe or other object left under train

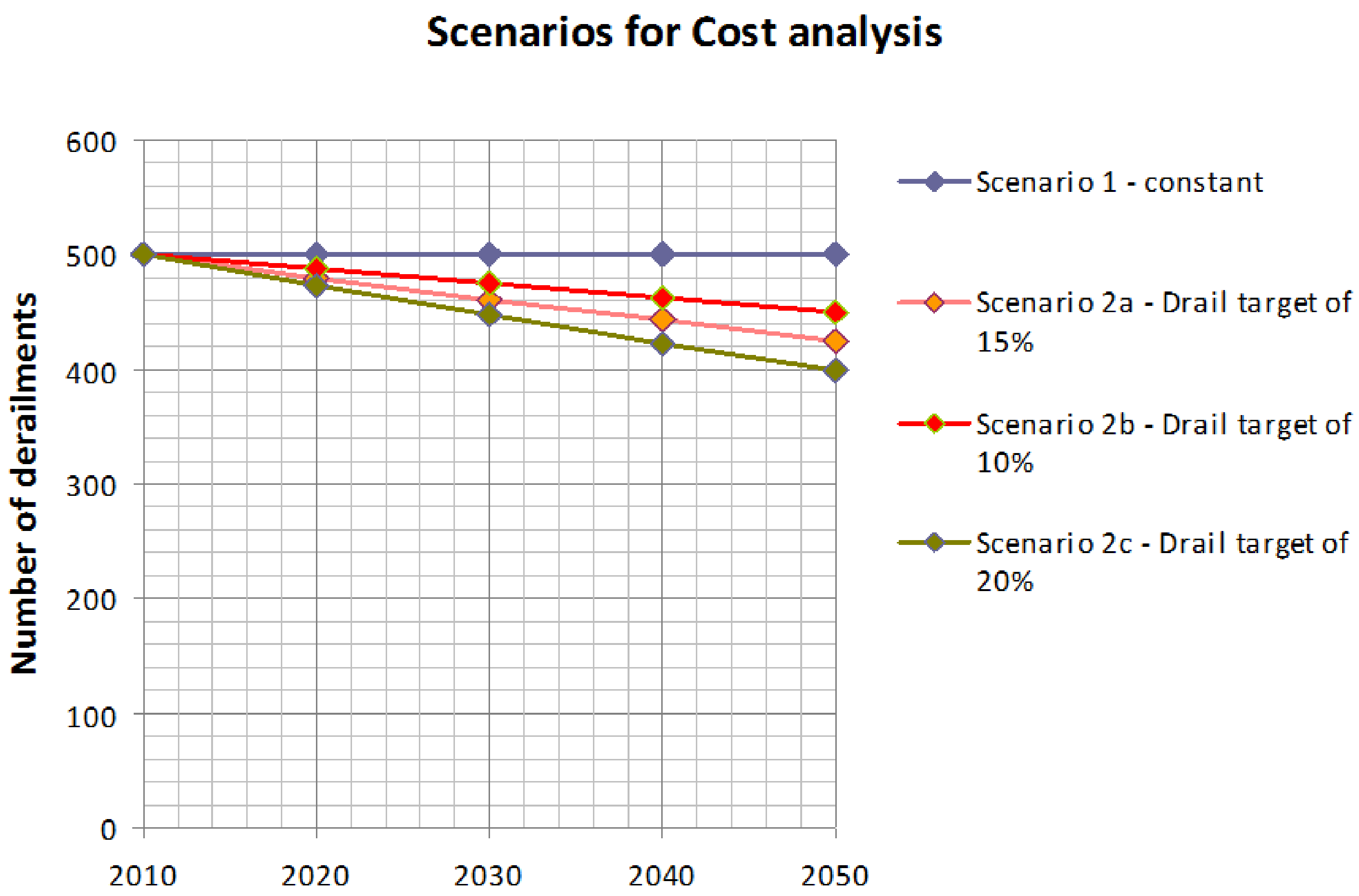
OVERALL RANKING OF DERAILMENT CAUSES IN **EUROPE**

1. **Hot axle box and axle journal rupture**
2. **Excessive track width**
3. **Wheel failure**
4. **Skew loading**
5. **Excessive track twist**
6. **Track height/cant failure**
7. **Rail failures**
8. **Spring & suspension failure**

TOP DOWN ANALYSIS

- Two scenarios were assumed on derailment:
  - Constant rate of accidents annually
  - Decreasing rate of accidents (based on target 10-20% reduction) annually
- We assumed 500 derailments per year as a starting point (500 derailments are assumed in other studies as well);
- We assumed 802,361 € (current prices) average cost of a derailment

TOP-DOWN ANALYSIS: RESULTS



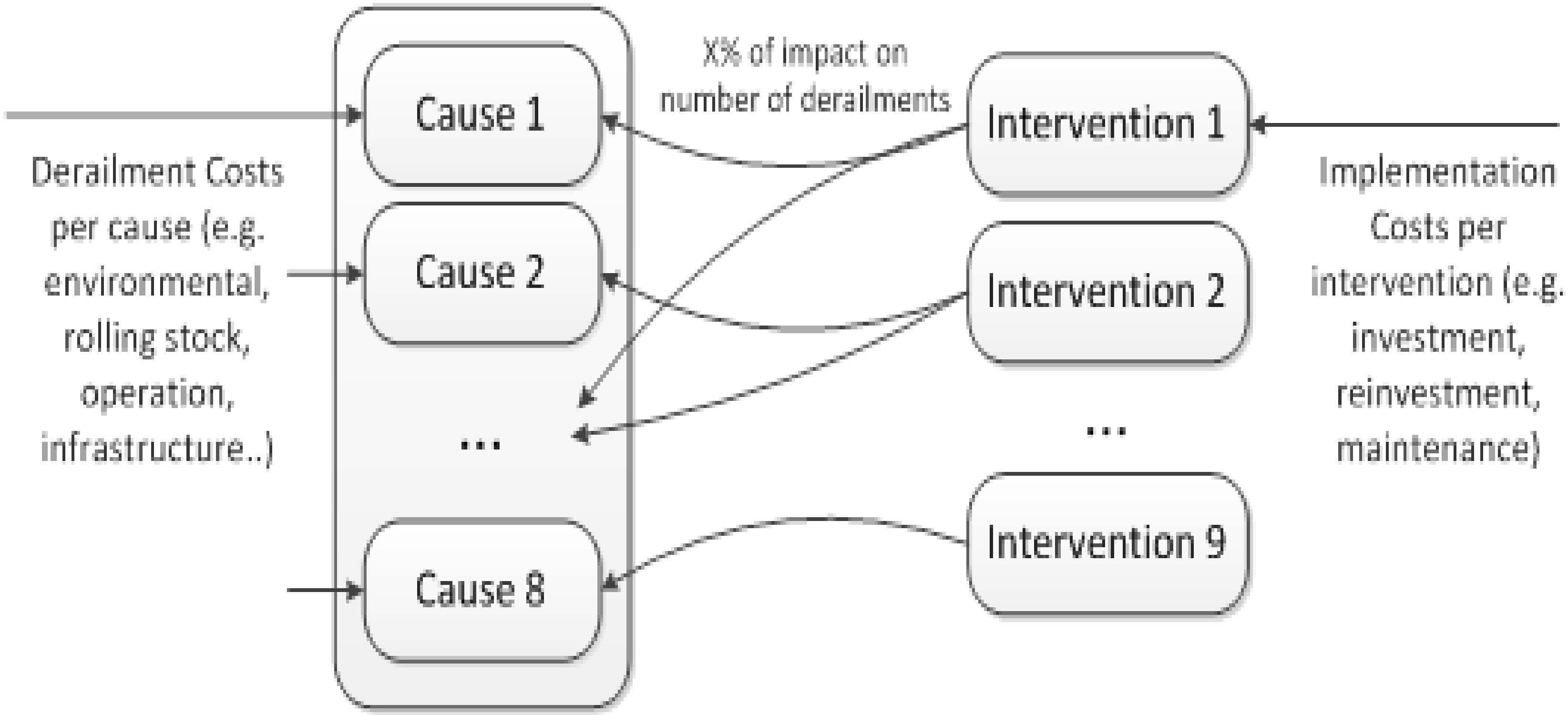
TOP-DOWN ANALYSIS: RESULTS

- The cumulative costs based on the number of accidents & average derailment cost add up to about 16b€
- The range of cost savings by 2050 can reach in the range (in the case of 10% to 20% reduction) is 0.8-1.6b€.

Costs (thousand €)	2010 annual costs	2030 annual costs	2050 annual costs	Cumulative Costs (2010-2030)	Cumulative Costs (2010-2050)	Cumulative costs decrease by 2050
Scenario 1 - constant derailment number	401,181	401,181	401,181	8,023,610	16,047,220	
Scenario2a - Decreasing accidents by 15% by 2050	401,181	369,870	341,003	7,721,932	14,841,202	**1,206,018**
Scenario 2b - Decreasing accidents by 10% by 2050	401,181	380,593	361,062	7,826,228	15,250,840	**796,380**
Scenario2c - Decreasing accidents by 20% by 2050	401,181	358,827	320,944	7,613,395	14,423,022	**1,624,198**

BOTTOM UP APPROACH

- In reality interventions can have an impact on different (multiple) causes



- We assumed for the moment 1 intervention to 1 cause
- BC ratio can be higher

COST PER DERAILMENT CAUSE AND BENEFITS PER INTERVENTION SETS

Derailment causes	Total costs in € (2012 values)	Set of intervention/mitigation	Impact	Avoided derailments/year
SET 1. Hot axle box and axle journal rupture	1,282,575 €	Hot box & hot wheel detector systems	12%	60
SET 2. Excessive track width	474,966 €	Track geometry measurement systems	8.60%	43
SET 3. Wheel failure	1,879,471 €	Axle load checkpoints	10.30%	52
SET 4. Skew loading	833,144 €	Axle load checkpoints	5.95%	30
SET 5. Excessive track twist	552,627 €	Track Geometry measuring systems	6.58%	33
SET 6. Track height/cant failure	281,922 €	Track Geometry measuring systems	3.40%	17
SET 7. Rail failures	587,025 €	Track internal inspection systems (NDT: Ultrasound, Eddy Current, Magnetic flux)	2.87%	14
SET 8. Spring & suspension failure	1,865,570 €	Axle load checkpoints	5.62%	28
Average derailment cost for specified causes	***1,094,639€***	***Total impact from the interventions/mitigations***	***55%***	***277***

BC RATIOS FOR EFFECTIVENESS = 1

Derailment causes	Y10	Y20	Y30	Y40
SET1. Hot axle box and axle journal rupture	**5,61**	**6,32**	**6,96**	**7,19**
SET2. Excessive track width	2,13	2,45	2,58	2,64
SET3. Wheel failure	1,83	2,06	2,30	2,30
SET4. Skew loading	1,56	1,73	1,90	1,90
SET5. Excessive track twist	1,71	1,78	1,99	1,95
SET6. Track height/cant failure	0,45	0,51	0,58	0,58
SET7. Rail failures	0,39	0,44	0,50	0,50
SET8. Spring & suspension failure	**4,60**	**5,02**	**5,49**	**5,48**

SENSITIVITY ANALYSIS

- A sensitivity analysis was conducted on the results of the benefit cost ratio (BCR) analysis with the following assumptions:
- Decrease in avoided derailments (i.e. effectiveness) by 10%
- Reduce costs by 10% (The relevant table is not presented due to limitation of time)
- Increase in costs by 10% (The relevant table is not presented due to limitation of time)
- Decrease in avoided derailments (i.e. effectiveness) by 10% and increase in cost by 10% costs

BC RATIOS FOR EFFECTIVENESS = 0.90

Derailment cause	Y10	Y20	Y30	Y40
SET1. Hot axle box and axle journal rupture	**5.05**	**5.69**	**6.27**	**6.47**
SET2. Excessive track width	1.92	2.20	2.32	2.37
SET3. Wheel failure	1.65	1.85	2.07	2.07
SET4. Skew loading	1.41	1.55	1.71	1.71
SET5. Excessive track twist	1.54	1.61	1.79	1.75
SET6. Track height/cant failure	0.41	0.46	0.52	0.52
SET7. Rail failures	0.35	0.40	0.45	0.45
SET8. Spring & suspension failure	**4.14**	**4.52**	**4.94**	**4.93**

BC RATIOS FOR EFFECTIVENESS = 0.9 AND INCREASING COSTS BY 10%

Derailment cause	Y10	Y20	Y30	Y40
SET1. Hot axle box and axle journal rupture	**4.59**	**5.17**	**5.70**	**5.88**
SET2. Excessive track width	1.74	2.00	2.11	2.16
SET3. Wheel failure	1.50	1.68	1.88	1.89
SET4. Skew loading	1.28	1.41	1.56	1.55
SET5. Excessive track twist	1.40	1.46	1.63	1.59
SET6. Track height/cant failure	0.37	0.42	0.47	0.47
SET7. Rail failures	0.32	0.36	0.41	0.41
SET8. Spring & suspension failure	**3.76**	**4.11**	**4.49**	**4.48**

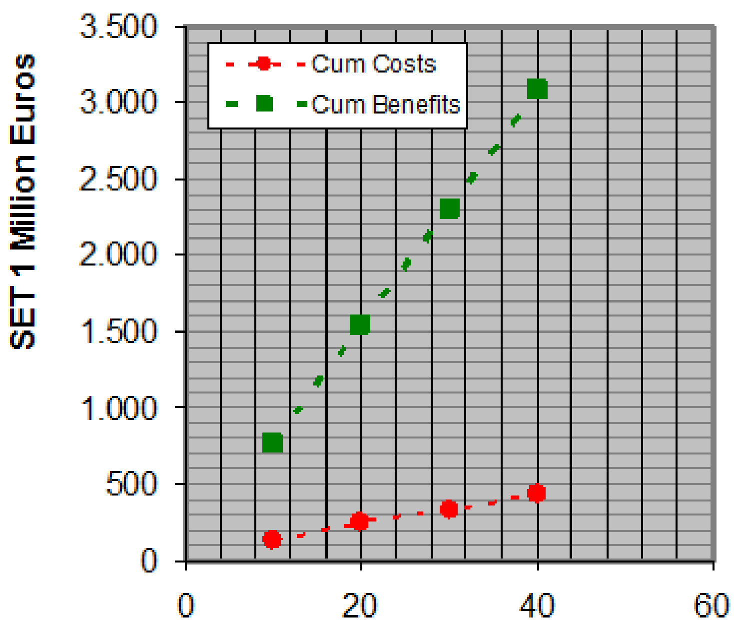
MAIN FINDINGS

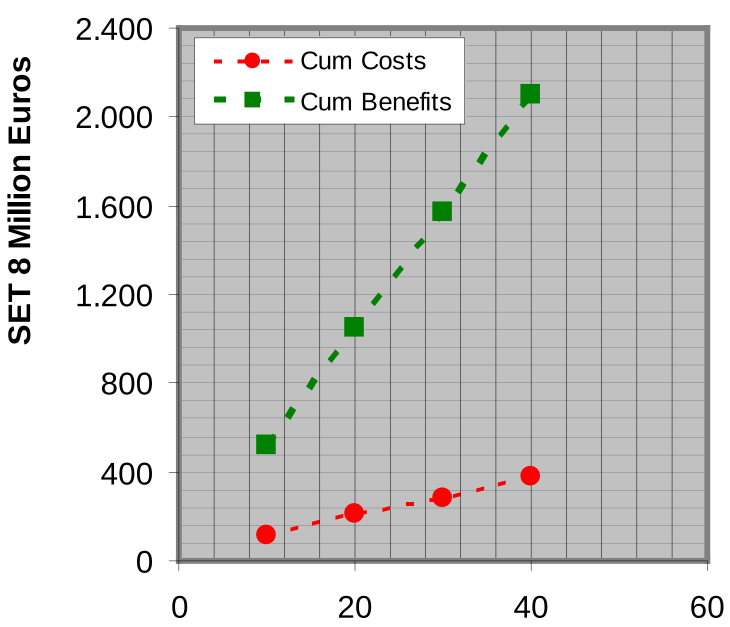
- Eight sets of intervention and mitigation techniques were analysed for eight sets of derailment causes;
- For SET 1 (hot axle box and axle rupture cause) and SET 8 (spring and suspension failure cause), the results were positive, reaching a benefit cost ratio more than 5 by 2050.
- For SET 6 (track height cause) and SET 7 (rail failures cause), the BC ratio remained under 1;
- For the remaining sets of mitigation techniques, the BC ratios remained less than 3.

SUITABLE MITIGATION TECHNIQUES

SET 1 - Hot axle box and axle journal rupture

SET 8 - Spring & suspension failure





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QUESTIONS AND DISCUSSION

D-RAIL

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SEVENTH FRAMEWORK PROGRAMME