Joint Sector Group
for ERA Task Force on wagon/axle maintenance
Intermediate results of FTA & FMEA – analysis

ERA, Lille
14th September 2011

European Wheelset FMEA & FTA

Aim of the methods FMEA & FTA

- The wheelset is one of the critical elements for rolling stock related derailments of freight trains.
- A systematic analysis of the initial effects (root causes) is not known to have been developed till now with harmonized methodologies.
- The aim of the Joint Sector Group (JSG) is to evaluate the risk level for wheelsets based on quantitative standards.
- With the “Failure mode and effect analysis (FMEA)” and “Fault tree analysis (FTA)” systematic methods are used for quantitative oriented risk assessments and improvements.
- Based on these objective results future measures to improve the safety and reliability can be better evaluated.

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Failure mode and effect analysis (FMEA)

- List of all possible types of failures with description of the next resulting failure
- Definition of functions for each element ➔ malfunctions will be evaluated
- Semi-quantitative evaluation ➔ Risk priority number (RPN)
- Overview of all potential failures with estimation of their importance
- Each failure net can be transferred in a FTA – analysis (quantitative analysis)

Failure following	Failure	Failure reason
derailment	broken journal	hot axle box

Failure following	Failure	Failure reason
broken journal	hot axle box	spalling outer race

Failure following	Failure	Failure reason
hot axle box	spalling outer race	loss of grease

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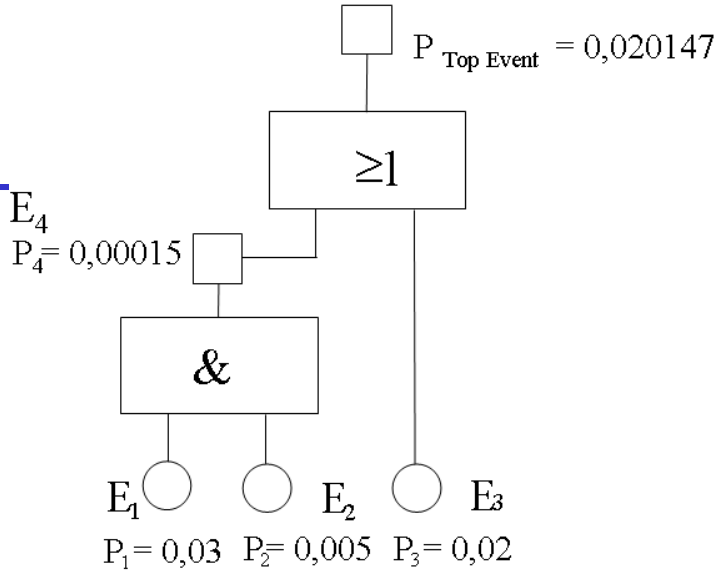

Fault tree analysis (FTA)

- **Quantitative analysis**
- **From top event (accident, worst case) down to the basic events, represented by branches of a tree**
- **FTA shows the path from each basic element with its probability to the top event.**
- **Combination of events with their probability (failure rate) by boolean algebra (and, or, …)**
- **1 top – event ➔ 1 failure tree**
- **Result:**
  - **Identification the most critical event path (basis to top event)**
  - **Identification of the risk contribution of the events for each level**
  - **Basis for target-oriented measures to reduce the risk level of the top event.**

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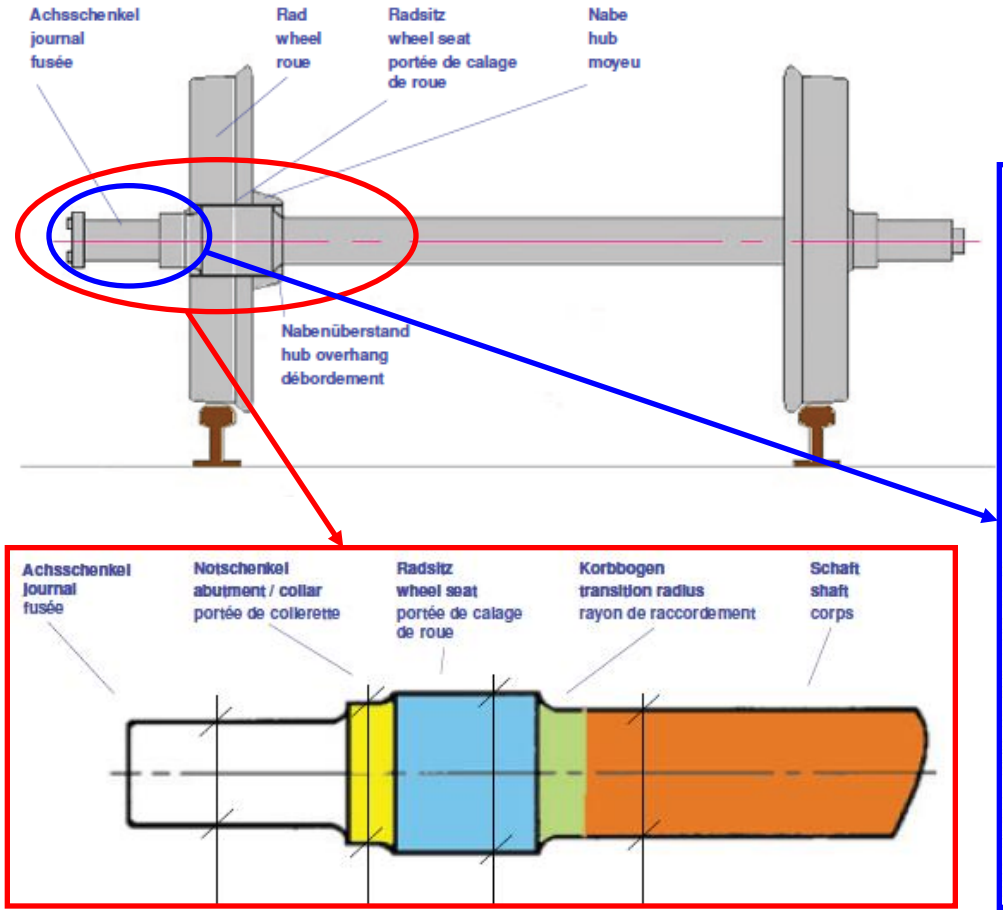
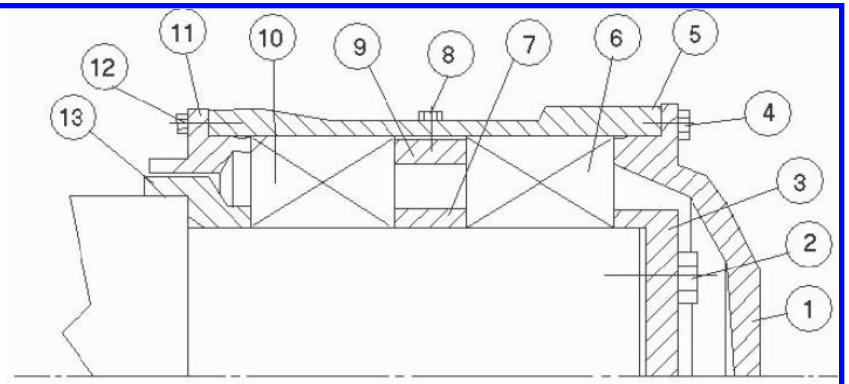
Wheelset and its components





Key

1 front cover
2 end cap bolt and lock
3 end cap
4 front cover bolt and lock
5 axle box body
6 outer bearing
7 internal spacer
8 lubrication point
9 external spacer
10 inner bearing
11 rear cover
12 rear cover bolt and lock
13 abutment ring

Source: Implementation of the Eropean Visual Inspection Guide Catalogue (EVIC), V 2.2, Joint Sector Group for ERA Task Force on wagon/axle maintenance, 2010-03

Source: EN 15313, Railway applications - In-service wheelset operation requirements - In-service and off-vehicle wheelset maintenance, 2010-04

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FMEA: Characteristics

➔ 152 root causes

Risk Priority Number (RPN) limit for intensive proovings:											150
Component	**Final failure:** (effect on the wheelset)	**Failure mode resulting next**	**Failure mode**	**Root cause**	**Severity**		**Detectability**		**Frequency**		**Risk priority number RPN**
3121 Solid wheel	derailment	wheel crack	broken solid wheel	mechanical damage	very low	4	moderate high	4	low: relative few failures	4	64
325 bearing	broken axle (journal / abutment)	hot axle box	spalling bearing	mechanical shock	moderate	6	little	8	low: relative few failures	4	192

FMEA: Results

➔ Risk priority number between 4 and 480

➔ ~ 20% of the root causes are over 150

➔ JSG concentrate on root causes over 150

➔ Distribution of root causes having a RPN over 150:

- 18%: axle
- 55%: Wheel (included tyred wheels)
- 27%: Bearing

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FTA: characteristics

- ➔ 1 top event: “Derailment due to wheelset damages”
- ➔ 118 root events
- ➔ 6 hierarchic levels of events (below the top event)
- ➔ Number of railways delivering data: 9
- ➔ Type of data: in most cases expert experience

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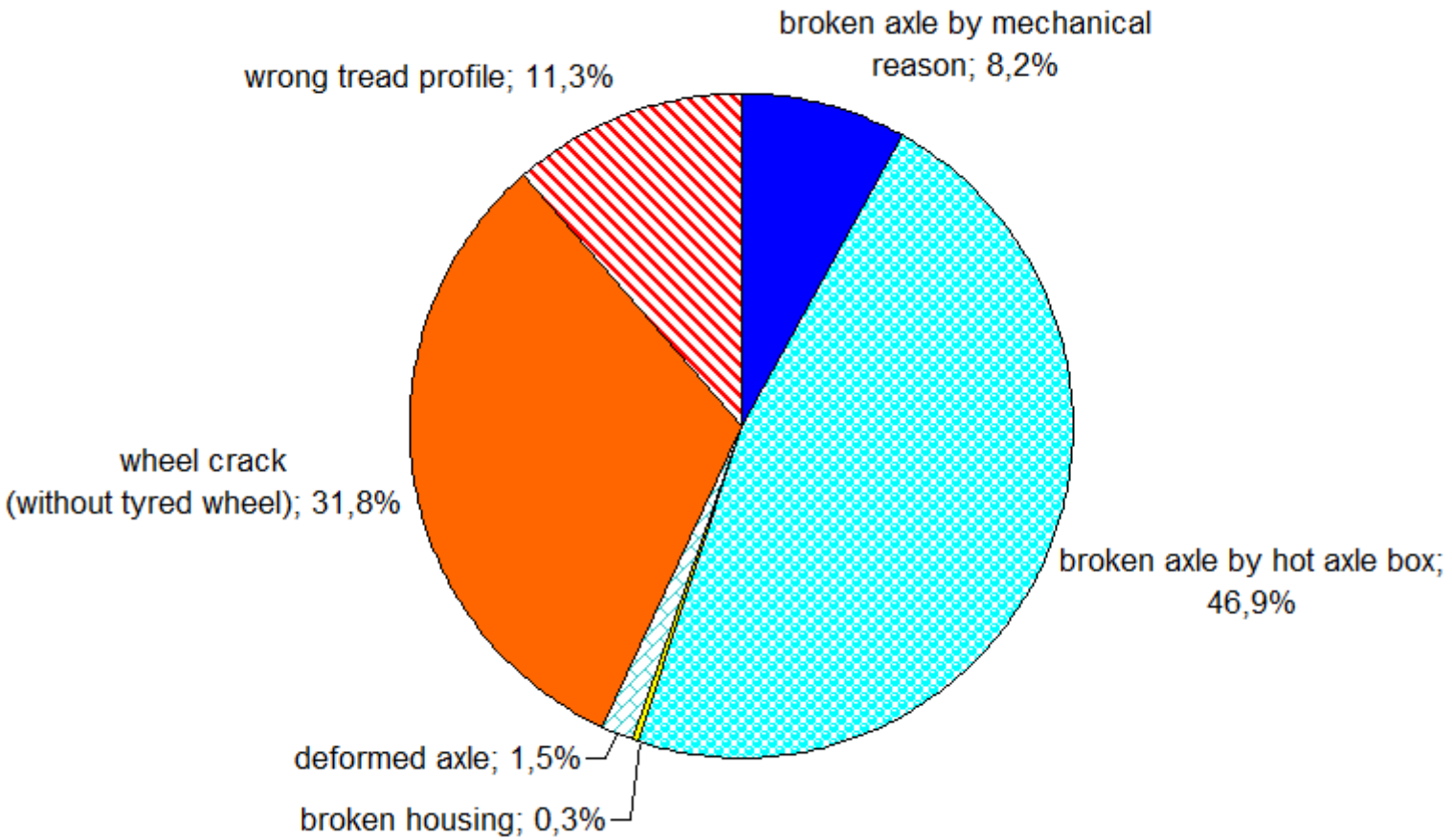
FTA: Results - excluding “tyred wheel”

(based on level 2 of the FTA)



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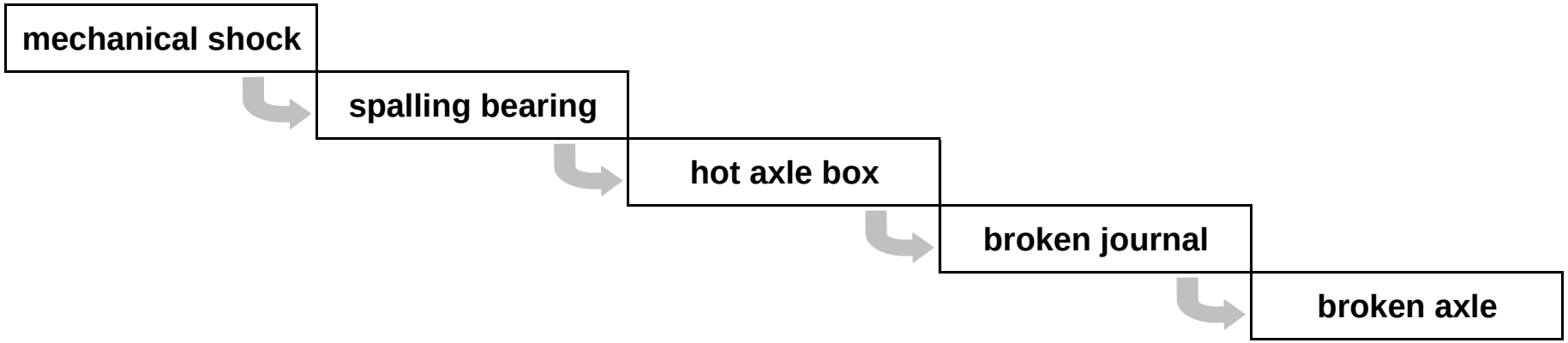
FTA: Discussion of the results - excluding “tyred wheel”

➔ **The results are extracted from the second level of events**

➔ **With 47 % the event “broken axle by hot axle box” takes over the majority**

➔ **most critical path:**



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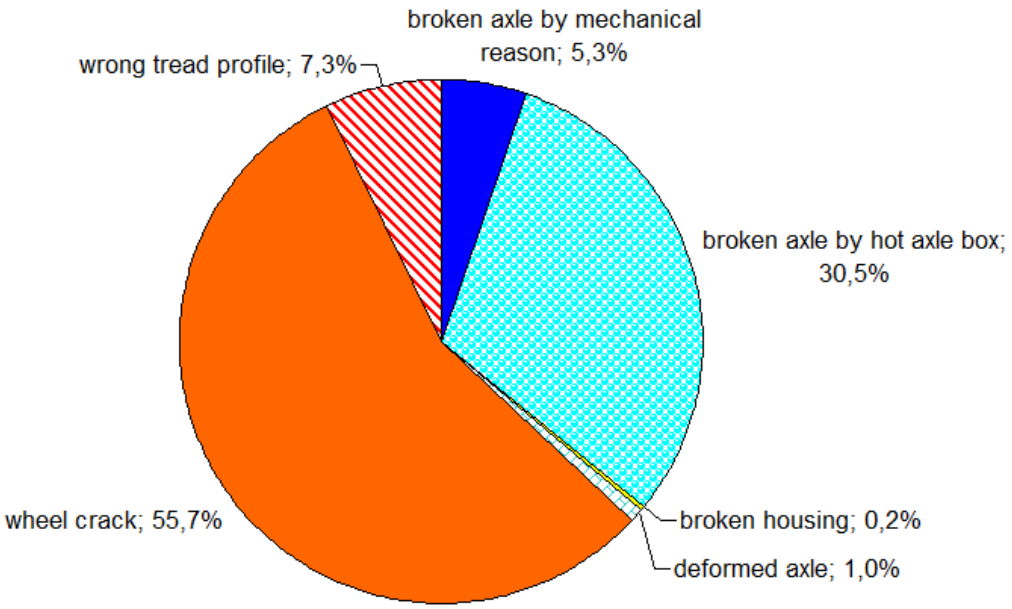
FTA: Discussion of the results - including “tyred wheel”

➔ **With ~ 56 % the event “wheel crack” takes over the majority, but:**

- **for the events “broken wheel center” and “broken tyre” <u>only 1 of 9 railways</u> stated figures**



➔ **most critical path:**

wrong tread profile

overloading by dynamic effects

excessive thermal stress

broken tyre

Wheel crack

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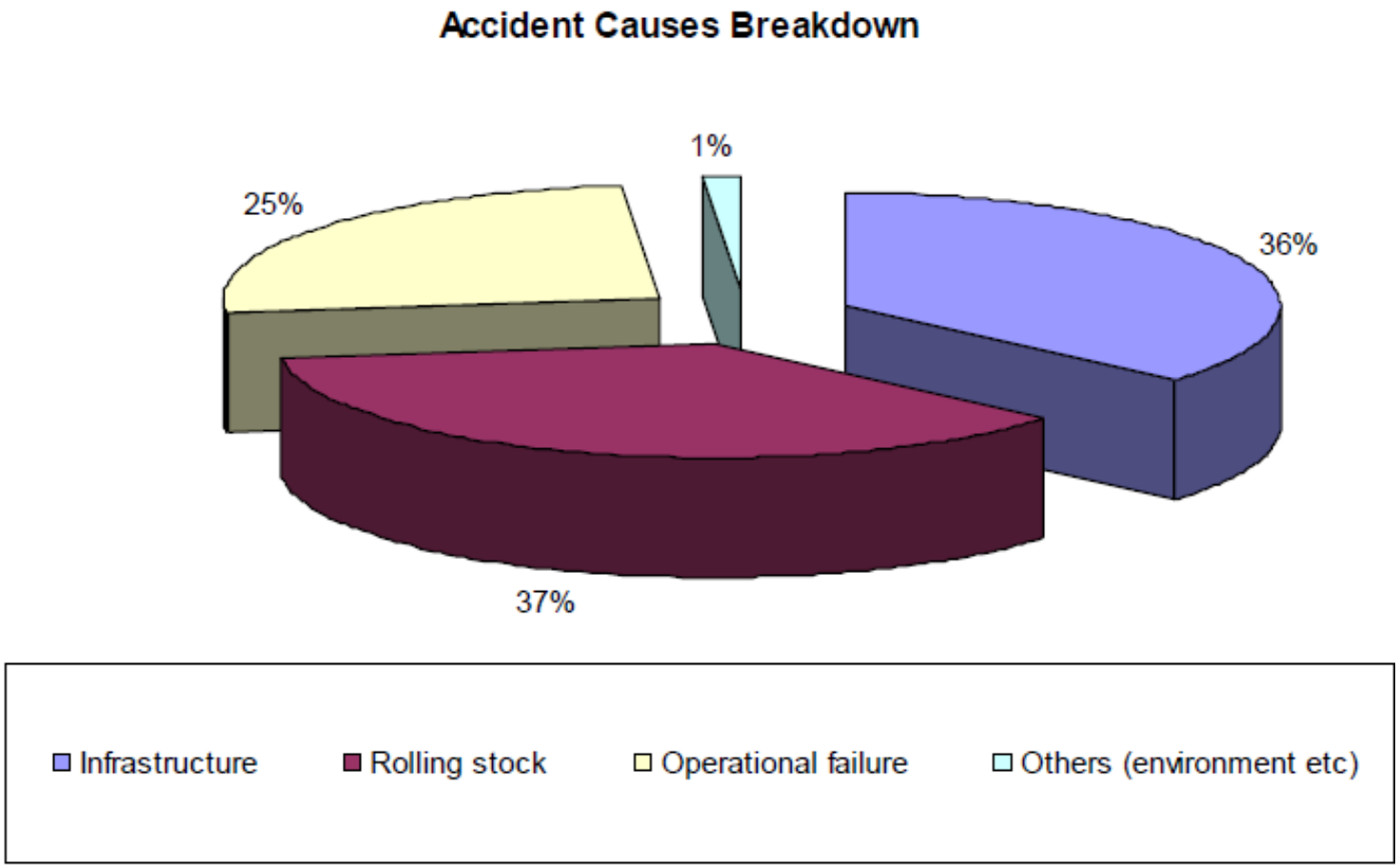
DNV – Study: Distribution of freight train derailment causes



Source: („Analysis of past derailments“, 06.May 2011

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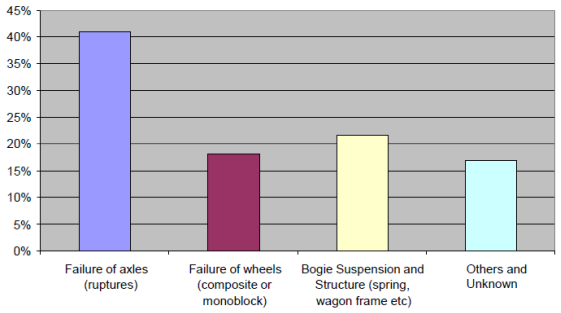
Comparison of the existing results: JSG – DNV - ERA

- ➔ **By ignoring the data of tyred wheels the results of JSG and DNV are close together**
- ➔ **Further research is needed to identify the most important root causes as basis for decisions**

Intermediate results of derailment study of DNV („Analysis of past derailments“, 06.May 2011):



ERA survey on axle failures in 2006 to 2009.
Here: only freight wagon axles:

Causes for axle failures of freight wagon in Europe	% from total of 38
Hot Axle Boxes	79%
Fatigue & corrosion	5%
Fatigue & metallurgic fault	8%
Fatigue (with no further information)	8%

	JSG (FTA August 2011)	**Den Norske Veritas** 155 derailments caused by wheelset (06.May 2011)	**ERA** Survey on broken axles 2010 (27 NSA's)
Failure / crack of wheels	**32%**	**32%**	no survey
Failure / crack of axles	**54%**	**68%**	only info of survey ==> 100%

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Reference to the preliminary results

- **First step for risk based quantification of wheelsets**
- **Reference to the degree of detailness:**
  - 9 railway undertakings delivered data, representing 1.027 Mio. wheelsets of 2 Mio. wheelsets in Europe (normal gauge)
  - The average annual mileage of a wheelset is 37,800 km with a span between 12,700 and 90,000 km
  - Overview of all types of construction of a component

- **Next steps to be discussed according to the results of the derail study**
  - Splitting up events in design of components
  - Splitting up events in manufacturer
  - Splitting up events in operation classes
  - Updating the FTA from “estimation” more to analysis
  - Updating the FTA from percentages to probabilities

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Conclusion

- This risk model concentrates only on the small number of failures caused by the wagon.
- Hot axle box is the most important issue.

Proposal

- JSG is concentrating on the bearing.
- JSG is evaluating measures to prevent bearing failures and detection methods.
- The JSG has to include representatives of infrastructure companies.

Thank you for your attention!