Analysis of railway accidents using the „Why-Because Analysis“
Accidents can only lead to improvements when we understand why something happened.

V-model of accident investigation:

- Accident
  - Collection of information
  - Accident reconstruction
  - Accident analysis
    - Root cause analysis
  - Answer to why it happened

- Global measurements
  - Relevance analysis
  - Transfer to related event types
  - Decrease occurrence of related events

- Lokal measurements
  - Decrease occurrence of event type
  - Analysis methods are crucial for ensuring improvement

Learning to improve.
An analysis method should provide a standard procedure, completeness and objectivity

Main threats in accident analysis
- quality of analysis depending on quality of analyst
- monocausal thinking
- direction of analysis and presentation of result influenced by (political) interests

Main requirements for analysis method
- standard analyzing procedure
- completeness - identification of all the root causes
- objectivity - unaffected to questions of “who is to blame” or political interests

Agenda of presentation
1. methods in accident analysis
2. introduction of Why-Because Analysis
3. analysis example using Why-Because Analysis
4. evaluations and conclusions
Why-Because Analysis was chosen out of many methods by benchmark analysis

1. Methods in accidents analysis

Multitude of Methods

- More than 40 methods developed since 1950
- Different approaches
  - event based
  - systemical
  - resilience engineering

Benchmark

- Benchmark of analysis methods (focus on railway accidents)
- Preselection of 11 out of 47 methods
- Detailed evaluation shows best fit for 4 methods
- Best fitting to requirements: Why-Because Analysis (WBA)
Why-Because Analysis focuses on cause and effect relations providing logical test questions to ensure completeness

**Approach**
- Accidents are caused by a combination of factors or conditions (similar to Swiss cheese model).
- Causal connections between the factors are analysed and visualized.

**Analysis**
- Up to required analysis-depth (-> root causes).
- Formal test (test questions) make sure of correctness of analysis.
- Result: Why-Because graph („cause and effect graph“).

**Example**

**Test 1:** Effect caused by these factors?  
Yes -> **causal sufficiency**

- Why?
- Because:
  - Impuls of egg
  - Eggshell brakes
  - Egg liquid inside

**Test 2:** Can single factor be emitted with same effect?  
No -> **necessary causal factor (NCF)**

- Mass of egg
- Velocity of egg
- Egg crashes on floor
- Certain floor material

Causal sufficiency & NCFs -> **causal completeness**

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Person lets egg fall from 1m

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Certain stability of egg shell
Why-Because Analysis analysis example: Derailment of InterCity train exiting Stuttgart main station

process of InterCity-derailment
- InterCity leaves platform in push-operation
- speeds up to ca. 38 km/h
- passes three points of various radius (S-curve 300m-190m-190m)
- traction vehicle and three last coaches derail within S-curve
- 5 people slightly injured & major damage

additional facts
- buffer damage
- Two more derailments with very similar circumstances (IC push-operation in S-curve Stuttgart main station)
All parameters were within regulations – no simple single cause explanation possible

<table>
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<tr>
<th>topic</th>
<th>parameter (excerpt)</th>
<th>within regulations?</th>
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<tr>
<td>infrastructure</td>
<td>condition of points and tracks</td>
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</tr>
<tr>
<td></td>
<td>track geometry (radius combination in S-curve)</td>
<td>✓</td>
</tr>
<tr>
<td>vehicle</td>
<td>buffer geometry, material, maintenance etc.</td>
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<tr>
<td></td>
<td>vehicle condition (maintenance history, etc.)</td>
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<tr>
<td>operation</td>
<td>force in push-operation</td>
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<tr>
<td></td>
<td>Velocity</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>local operation regulations</td>
<td>✓</td>
</tr>
</tbody>
</table>

Arising question: „what was different from usual operation that could have caused the derailment?“
Analysis of journey data shows anomalies in acceleration of derailed trains

Comparison of InterCity journey data in push-operation (same track in Stuttgart main station)

Observations

- IC push-operations with no derailment accelerate before entering S-curve
- IC push-operation with derailments show similar acceleration behavior in S-curve

Effects in S-curve

→ increased force on buffers in acceleration phase (see graphic)
→ shorter buffer overlapping
→ coach bodies function as oscillation arm
→ Dynamical behavior of coaches due to velocity and acceleration
Why-Because graph identifies all distributing causal factors

**Legend:**
- Cause ➔ Effect

- Derailment of three coaches and traction vehicle

- Coach buffer levers coach out of track

- Coach buffer bends down

- High force on buffer
  - Force from traction vehicle
  - Acceleration in unusual sector

- Short overlapping of buffers
  - Coach position close to traction vehicle
  - Push-operation

- Buffer stability
  - Buffer geometry
  - Deflection of coach body
  - Geometry of track
  - Length of coach body and neighbor coach

- Buffer material and design

Simplified version of Why-Because Graph
The combination of 7 factors caused the derailment; for improvement these factors are possible fields of action.
Why-Because Analysis has great potential in railway accident analysis

**experience from example**
- eliminated discussions about „who is to blame“
- efficient for internal communication
- helped to focus on relevant fields of action
- doesn’t replace experience and expertise

**evaluation and conclusions (approx. 15 real life cases)**

**requirements as stated above**
- **standard** analyzing procedure
- **completeness** - identification of all the root causes
- **objectivity** - unaffected to questions of „who is to blame“ or political interests

**WBA requirement-evaluation**
- provides standardized method
- ensured by causal completeness tests
- objective result: Why-Because graph

**conclusions**
- further usage in upcoming cases
- potential to become standard part in accident analysis
Selection of railway accidents where a Why-Because Analysis was applied (mostly by scientific institutions)

- **Brühl (DE)**
  - Derailment - 2000
  - 9 dead
  - 149 injured
  - 50 Mio. DM damage

- **Eschede (DE)**
  - Derailment - 1998
  - 101 dead
  - 88 injured
  - 300 Mio. DM damage

- **Ladbroke Grove (UK)**
  - Slanting collision - 1999
  - 31 dead
  - 523 injured
  - High damage

- **Asta (NOR)**
  - Frontal collision - 2000
  - 19 dead
  - High damage

Thank you very much for your attention!