Towards a Hybrid Approach for Incident Root Cause Analysis

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Overview

- Introduction
- Necessary Aspects in Incident Analysis
- Case Study: Herald of Free Enterprise (HFE)
  - Story of the Accident in a Nutshell
  - Time-Actor Diagram
  - Why-Because Graph
  - STAMP Diagram
- Comparison and Relationships
- Conclusion and Way Forward
Introduction

- Increased interest in causal analysis methods
  - IRIA2002
  - Bieleschweig workshops, 2002&2003
- Several new approaches available
  - Why-because analysis (WBA, Ladkin, University of Bielefeld)
  - Systems-Theoretic Accident Modeling and Processes (STAMP, Leveson, MIT, Boston)
  - Safety by Organizational Learning (SOL, Wilpert/Fahlbruch, TU Berlin)
  - Events and Causal Factors diagram (ECF, Johnson, U of Glasgow)
  - Etc.
- No standardised or commonly agreed way to analyse causes and present results of such an analysis
- Different investigators or different sectors have very different procedures and put emphasis on different issues.
Necessary Aspects in Incident Analysis

- Organisational factors play a major role in many incidents, but are they sufficient?
- What kinds of aspects are important in a root cause analysis?
- Experience gained from several case studies shows the importance of:
  - Time and sequence aspects of events
  - Causal relationships
  - Organisational factors
- There may be more aspects, but these are deemed necessary.
Case Study: HFE

- A formal report is available (Sheen, 1987), which is the only source used.

- It is a real case and the results from the various analyses fit almost entirely into a single paper. In many other cases, even the results of a single analysis will not fit into one paper.

- The authors were not familiar with the case before and the case does not come from their usual application domain. This could make it easier to concentrate on methodology issues and not get bogged down in the technical details of the case.

- Each coauthor was responsible for one particular analysis. Only the results underwent a peer review to ensure correctness.
Story of the Accident in a Nutshell

- The HFE left Zebrugge harbour with her bow doors open.
- She passed the outer mole and increased speed.
- Water flooded onto the lower car deck.
- The ship became destabilised and capsized.
- Of the 459 on board, 189 died.

Some facts the investigation brought to light:

- The Assistant Bosun, whose immediate responsibility it was to close the bow doors upon departure, was asleep in his cabin.
- The Chief Officer, responsible for ensuring door closure, thought he saw the Assistant Bosun going to close the doors.
- The Captain always assumed that the doors were safely closed unless told otherwise.
Rail Automation

2nd Officer

Supervises loading of vehicles on G deck

Bosun

Goes to assigned station

Maintenance activities

Assistant Bosun

Goes to cabin and falls asleep

Ship

Ballast tanks filled for vehicle loading

Reverses and leaves harbour

Time-Actor Diagram

Master

On bridge

Chief Officer

Supervises loading of vehicles on G deck

Goes to messroom

Goes to bridge

17:50 18:00 18:05 18:24 18:30

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2003-06-26 Page 7
Why-Because Analysis

- Define an event as the starting point. In our case, we started with the capsizal of the Herald of Free Enterprise.

- Ask what the immediate causal factors were and repeat this step for each factor identified.

- Check if each causal factor is individually necessary for the event it is connected to. Based on Lewis's formal definition of causality, B is a necessary causal factor of A if: had B not happened, A would not have either.

- Check whether the causal factors connected to a particular event are jointly sufficient for it.
Why-Because Graph: Herald of Free Enterprise, 1987-03-06

0
Herald of Free Enterprise (HFE) capsizes

0.1
HFE becomes unstable

0.1.1
Water accumulates along entire length of one side of the G deck (lower car deck)

No subdividing bulkheads present

Water flows onto main car deck

1.1
Bow wave rises above bow spar

1.1.1
HFE is trimmed by the head (0.8 m)

1.1.1.1
Not all the water is pumped out of tanks before leaving port

1.1.1.2
Water is pumped into bow tanks for car loading

1.1.2
Master increases speed setting combinator 6 after passing outer mole

1.1.2.1
Bow doors are open

1.1.2.1.1
Herald of Free Enterprise, March 6th, 1987

1.1.2.1.1.1
Master assumes that bow doors were closed on the way to the outer mole (18:05-18:24)

1.1.2.1.1.2
Standing orders contain "negative reporting"

1.1.2.1.1.3
Suggested improvement based on near misses dismissed by Management

1.1.2.1.2
Officer loading G deck did not ensure that bow doors were secure when leaving port (violation of instruction issued in July 1984)

1.1.2.1.2.1
There was no indicator on the bridge to indicate status of bow doors

1.1.2.1.2.2
Master cannot see whether bow doors were open or closed

1.1.2.1.2.3
It was common practice to assume the bow doors were secured when leaving port

1.1.2.1.1.1
Assistant Bosun is released from supervision work by Bosun

1.1.2.1.1.2
Assistant Bosun is tired

1.1.2.1.2.1
Assistant Bosun does not close bow doors

1.1.2.1.2.2
It was common practice to assume the bow doors were closed if they were not reported open

1.1.2.1.2.3
There was no indicator on the bridge to indicate status of bow doors

1.1.2.1.2.4
Suggested improvement based on near misses dismissed by Management

1.2
Bow doors are not closed on the way to the outer mole (18:05-18:24)

1.2.1
Assistant Bosun does not close bow doors

1.2.1.1
Assistant Bosun is asleep in cabin

1.2.1.2
Officer loading G deck did not ensure that bow doors were secure when leaving port (violation of instruction issued in July 1984)

1.2.1.1.1
Assistant Bosun is released from supervision work by Bosun

1.2.1.1.2
Assistant Bosun is tired

1.2.1.2.1
Assistant Bosun does not wake up at harbour station call (18:00)

1.2.1.2.2
Assistant Bosun does not wake up at harbour station call (18:00)

1.1.1.1.1
Cost of high-capacity pump considered prohibitive

1.1.1.2
Capacity of ballast pump too low

1.1.1.3
Time pressure

1.2.1.1.1
Request for high-capacity pump rejected
Why-Because Graph: Herald of Free Enterprise, 1987-03-06

0
Herald of Free Enterprise (HFE) capsizes

0.1
HFE becomes unstable

0.1.1
Water accumulates along entire length of one side of the G deck (lower car deck)

2
No subdividing bulkheads present

1
Water flows onto main car deck

1.1
Bow wave rises above bow spade

1.2
Bow doors are open
Why-Because Graph: Herald of Free Enterprise, 1987-03-06

1.1 Bow wave rises above bow spade

1.1.1 HFE is trimmed by the head (0.8 m)
- 1.1.1.1 Not all the water is pumped out of tanks before leaving port
  - 1.1.1.1.1 Request for high-capacity pump rejected
    - 1.1.1.1.1.1 Cost of high-capacity pump considered prohibitive
  - 1.1.1.2 Capacity of ballast pump too low
    - 1.1.1.2.1 Time pressure

1.1.2 Water is pumped into bow tanks for car loading

1.1.3 Bow doors are open
- 1.1.3.1 Master increases speed setting combinator 6 after passing outer mole

1.2 Bow doors are open

Herald of Free Enterprise, March 6th, 1987
Why-Because Graph: Herald of Free Enterprise, 1987-03-06

1.1 Bow wave rises above bow spade

1.2 Bow doors are open

1.1.2 Master increases speed setting combinator 6 after passing outer mole

1.1.2.1 Master assumes that bow doors were closed on the way to the outer mole (18:05-18:24)

1.1.2.1.1 Master cannot see whether bow doors are open or closed

1.1.2.1.2 It was common practice to assume the bow doors were closed if they were not reported open

1.1.2.1.3 There was no indicator on the bridge to indicate status of bow doors

1.1.2.1.1.1 Design of bow doors (closing horizontally)

1.1.2.1.2.1 Standing orders contain "negative reporting"

1.1.2.1.3.1 Suggested improvement based on near misses dismissed by Management
Why-Because Graph: Herald of Free Enterprise, 1987-03-06

1.2
Bow doors are open

1.2.1
Bow doors are not closed on the way to the outer mole (18:05-18:24)

1.2.1.1
Assistant Bosun does not close bow doors

1.2.1.2
Officer loading G deck did not ensure that bow doors were secure when leaving port (violation of instruction issued in July 1984)

1.2.1.1.1
Assistant Bosun is asleep in cabin

1.2.1.1.2
Assistant Bosun is released from supervision work by Bosun

1.2.1.1.1.1
Assistant Bosun is tired

1.2.1.1.2
Assistant Bosun does not wake up at harbour station call (18:00)
STAMP

- The basic concept is not an event, but a constraint.
- Systems are viewed as socio-technical control structures, with each level imposing constraints on the activities of the level beneath it.
- Accidents result from inadequate control of safety-related behaviour.
- STAMP provides a classification of control flaws leading to hazards:
  - Inadequate control actions
  - Inadequate execution of control actions
  - Inadequate or missing feedback
## Comparison

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<thead>
<tr>
<th></th>
<th>Pros</th>
<th>Cons</th>
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</thead>
<tbody>
<tr>
<td><strong>TAD</strong></td>
<td>■ Good overview of what happened</td>
<td>■ More abstract factors not represented</td>
</tr>
<tr>
<td></td>
<td>■ Clear structuring of the incident causes</td>
<td>■ Strict definition of causality may be a hindrance when it comes to human or organisational factors</td>
</tr>
<tr>
<td><strong>WBG</strong></td>
<td>■ Formal definition of causality</td>
<td></td>
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</tbody>
</table>
## Comparison

<table>
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<tr>
<th>STAMP</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Systematic uncovering of organisational structures</td>
<td>- A structured presentation of results was not available at the time of our analysis.</td>
</tr>
<tr>
<td></td>
<td>- Directs you to ask revealing questions</td>
<td>- Retrospective application only useful if investigation report is excellent</td>
</tr>
<tr>
<td></td>
<td>- Can be used even before an incident or accident happens</td>
<td>- Enormous effort required for analysis</td>
</tr>
</tbody>
</table>
Relationships

- The actors in the TAD are only a subset of the entities in the STAMP diagram.
- Events and states in the TAD do not appear in the WBG unless they are causal factors.
- Many of the causal factors in the WBG do not appear in the TAD.
- Not all causal factors in the WBG have a corresponding control flaw in the STAMP diagram and vice versa.
Relationships

WBG

STAMP

TAD
Conclusion

- No single analysis technique proposed so far covers all necessary aspects.
- A hybrid approach should be adopted which combines the best features of various techniques:
  - TAD diagram or similar representation of time and sequence properties
  - WBG, to acquire a clear overview of the causal factor landscape
  - STAMP or SOL, for the identification of contributory organisational or human factors
  - Extension of WBG, to include these factors even if they do not pass the strict causal factor test
Way Forward

- The "Bieleschweig workshops" will evaluate the methods for benchmark examples using a harmonised catalogue of criteria.
- The hybrid approach has to be scaled according to incident complexity.
- The cost of applying all methods as part of an industrial root cause analysis programme is prohibitive and justified only in exceptional cases.
- SOL and other techniques should be evaluated and adapted.
- A hybrid approach should be applied to real railway incidents.