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What you find is not always what you fix – How other aspects than causes of accidents decide recommendations for remedial actions

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Abstract: In accident investigation, the ideal is often to follow the principle "what-you-find-is-what-you-fix", an ideal reflecting that the investigation should be a rational process of first identifying causes, and then implement remedial actions to fix them. Previous research has however identified cognitive and political biases leading away from this ideal. Somewhat surprisingly, however, the same factors that often are highlighted in modern accident models are not perceived in a recursive manner to reflect how they influence the process of accident investigation in itself. Those factors are more extensive than the cognitive and political biases that are often highlighted in theory. Our purpose in this study was to reveal constraints affecting accident investigation practices that lead the investigation towards or away from the ideal of "what-you-find-is-what-you-fix". We conducted a qualitative interview study with 22 accident investigators from different domains in Sweden. We found a wide range of factors that led investigations away from the ideal, most which more resembled factors involved in organizational accidents, rather than reflecting flawed thinking. One particular limitation of investigation was that many investigations stop the analysis at the level of "preventable causes", the level where remedies that were currently practical to implement could be found. This could

potentially limit the usefulness of using investigations to get a view on the “big picture” of causes of accidents as a basis for further remedial actions.

Keywords: Accident investigation, bias, stop rule, method, experience feedback, remedial actions

1. Introduction

To learn from events is often celebrated as one of the key principles of effective safety management. Experience feedback from events take many forms such as collecting statistics and performing in-depth analysis of event (Kjellén, 2000). A basic assumption underlying accident investigation is that analysis of specific events will reveal patterns of underlying causes and conditions that if addressed by the right remedial actions can prevent further events. The distinction often drawn between retrospective (analysis of events) and prospective (risk analytical) methods is intuitively understandable but incomplete: risk analysis requires the experience from analysis of previous events and event analysis implies that the weaknesses found are the ones that impose risk. Consequently, in accident investigation, an ideal is often to follow the principle "what-you-find-is-what-you-fix", which is clearly a guiding principle for instance in Swedish accident investigation manuals and guidelines (Lundberg et al. 2009). (It is obviously impossible to fix something that has not been 'found,' i.e., which has not basis in reality. Even so, it happens every now and then, cf., below.) Another way to state this principle is: if an accident happens determine the causes and implement suitable arrangement to eliminate the causes and/or their effects. This is also a goal that guides research: there are numerous articles and books describing methods for finding the right causes, as well as articles describing "accident models", that is generic models of factors and their relations that can provide support for finding cause-effect relationships behind accidents (e.g. Heinrich, 1931; 1934; Gordon, 1949; Lehto and Salvendy, 1991; Svenson, 1991; Kjellén, 2000; Hollnagel, 2004; Leveson, 2004; Sklet, 2004; Factor *et al.*, 2007; Santos-Reyes and Beard, 2009). Fewer studies (e. g. Elvik, 2010) focus on difficulties of fixing what has been found. Modern accident models focus on factors and relations other than those focusing on humans closest to the events. Such approaches are based on the idea that numerous factors and conditions in a complex socio-technical system may have influence on accidents: including political and organizational factors, cultural factors, and issues of power relations, technological development and so forth (Hollnagel, 2004; Leveson, 2004; Santos-Reyes and Beard, 2009). This extension of the scope of issues relevant for understanding accident propagation has lead to a deeper understanding of safety. Accident models of today often include nuanced ideas about "factors" behind accidents as well as elaborated ideas about cause-effect relations. Somewhat surprisingly, however, the same factors that often are highlighted in modern accident models are not perceived in a recursive manner to reflect how they influence the process of accident investigation in itself. Another way to rephrase this issue is the following: how does the same organizational context that is responsible for accidents impose constrain on the methods and understanding of accident investigation and associated methods. In this article we have set out to approach some of these issues by means of interviews with accident investigators from various branches. Our goal has been to reveal patterns of influence affecting accident investigation practices that presumably represent the same roots as those often claimed to be "root causes" to accidents.

2. Purpose

Our purpose is to reveal constraints affecting accident investigation practices that lead the investigation towards or away from the ideal of "what-you-find-is-what-you-fix".

3. Method

We used the interview guide in the Appendix to guide the interviews. During the interviews, the informants could also initiate topics of their own (Question 4.4. was not used in the interviews with the health care sector, interviews 17-22, Table 1.). Interviews 1-10, Table 1, and the same interview guide, was used as data in a previously published study (Korolija and Lundberg, 2010).

The interview guide (see Appendix) covered five areas: background information about the informant, the phases of an investigation, their support in the form of accident investigation manuals, accident models, and safety culture. The first section covered the experience of different areas of accident investigation of investigators and their professional networks for exchange of experiences. The second section regarded investigation activities. It focused on previously neglected activities (Lundberg *et al.*, 2009) in particular the design or selection of measures and the transition from analysis to measures. However, there were also questions about the investigation at large, about what activities were focused in the investigation practices. The third section focused on their view on accident investigation manuals and other supporting documentation, focusing on whether they found that it reflected current practices, were lagging behind, or described practices that had not yet been implemented. In the fourth section, the interviews focused on accident models. The questions were designed to guide the discussion both to what extent simple linear accident models were used (Heinrich, 1934) versus more complex linear models that take underlying factors into account (Reason, 1997). Moreover, they covered more recent factors and models such as resilience (Lundberg and Johansson, 2006), and safety culture (Rollenhagen, 2005) which was in focus in section five.

Twenty-two semi-structured interviews were conducted during 2007 (see Table 1). The informants in the transportation domain (1-10) were all male, whereas seven of the remaining 12 in the other domains were female. 10 of them had between 1-5 years of experience with investigation, the others had longer experience, and most of the 10 had about 4 years of investigator experience. The remaining 12 had long experience of investigation. Most of them had gone through few courses in accident investigation. Two of them (with the longest experience) had not gone through any courses. The first author conducted interviews 1-16, interviews 14-22 were conducted by a masters student. The interviews lasted between 45 and 108 minutes, depending on the style of talk by the informant. Some presented longer comments and examples, whereas others gave shorter responses.

The interviews were recorded (audio only) and transcribed. A print of the questions was available to the informants during the sessions. During the interview, the analyst departed from the interview guide either to ask follow-up questions, to skip questions already covered by answers to a previous question, or to elaborate or explain a question further.

Table 1
Informants

N	Domain
3	Rail
3	Maritime
4	Road
3	Work, general
3	Nuclear
6	Patient safety

The analysis was conducted by reading through the data and noting factors to be considered when analyzing or designing remedial actions. The notes and the data was entered into a database, with a total of 207 excerpts (some lines of transcription) regarding constraints, and sorted into four general tables, concerning constraints during investigation (58 excerpts), during design and selection of remedial actions (111 excerpts), the stop rule for going from analysis to design (15 excerpts), and quality criteria for investigations. (28 excerpts) Excerpts could appear in more than one category since people sometimes talked about several subjects in the same excerpts. The excerpts were then sorted into more narrow categories, as presented in the results section below. References to the particular excerpts were finally removed, and replaced with a general reference to the domain, to avoid the identification of informants. In some particularly sensitive cases, the reference to the domain was also removed. Excerpts in the text below have been translated from Swedish, and corrected to become easier to read (false starts, and language flaws common in speech, have been corrected).

4. Bias in accident investigation

Previously, a need for research on real-world accident analysis has been requested, to find sources of bias that actually occur (Woodcock, 1995). However, some sources of bias in accident investigation are well known. Johnson (2003) lists several biases that can affect investigation, for instance the following: *Author bias*, a reluctance to accept findings from other people's investigations. *Confirmation bias*, a tendency to confirm pre-conceived causes. *Frequency bias*, a tendency to classify causes in common categories. *Political bias*, where the status of an individual gives him or her undue influence on the attribution of causes. *Sponsor bias*, where the attribution of causes are influenced by the risk of damaging the reputation of the investigator's own organization. *Professional bias*, where causes that are the most acceptable to colleagues of the investigator are chosen. Svensson, Johansson Lekberg (1999) moreover demonstrated bias based on engineering versus psychology background of investigators, regarding analysis of causes. The engineers tended to attribute more causes to human factors than to technical errors. Their study also found that the purpose of the investigation had a major impact. Legal analyses attributed blame to an individual whereas an analysis based on the accident evolution and barrier function method instead pointed at other factors. It should however be noted that different methods have historically had different foci – for instance, Heinrich (1931) promoted a focus on the most easily preventable causes that were most proximate to the accident. The focus on certain aspects to the exclusion of others, the accident model, is a well known bias in investigation (Leveson, 2004). There is however a belief in literature that good methods can reduce bias (Knox and Eicher, 1992; Svensson *et al.*, 1999).

5. Results and discussion

Our interviews exemplified many factors that drive the investigation towards the “what-you find-is-what-you-fix” ideal. There were, however, also many examples of constraints that make the investigation go in other, less desirable directions. In the following two sections, we first describe and discuss factors affecting data collection and analysis, and then factors that affect the design or selection of remedial actions.

5.1. Practical considerations during investigation (data collection and analysis)

5.1.1. Investigation competences – what you can fix depends on what you are able to understand

In order to understand the causes of an event – and consequently what should be fixed – it was common for the investigators to engage people with various expert competences, such as associated with various equipment in nuclear facilities (nuclear), chemistry (maritime accidents), cars, biomechanics (road), electricity and rail systems (rail). Several mentioned that they often engaged colleagues to get different viewpoints on the investigation.

Experience of the practice that is under investigation. As one investigator expressed it, it is often necessary to be able to “see things through *their* eyes” to understand how *they* work with something and why. Experience of such practices could be from own experience (maritime accidents), from having previous investigation experience (rail) or achieved by bringing someone in from the practice in question (patient safety).

“I focus mainly on the accident, but it is also very important to understand the affected practice. And then the person who knows the practice is central; otherwise there will be lots of opinions. One needs to understand the normal practice to understand what went wrong.” (Excerpt from interview in the patient safety domain)

General investigation experience. One investigator also mentioned that general investigation experience is important, since lack of experience might make people stop at the first thing that they find that’s gone wrong. For instance, stopping at a broken piece of equipment as a cause, rather than factors related to the failure (nuclear).

The aspect of bringing in relevant competence in the context of an investigation is of course not surprising and more or less a standard advice in accident investigation manuals. However, the problem here is to determine which kind of competence that is assumed as relevant. If the accident investigator does not have a sufficiently broad scope of possible relevant competencies in mind at the start and in subsequent phases of the investigation, then one could hardly expect that the relevant competencies are called into the investigation. A possible strategy to conquer some of these problems would be to educate accident investigators in a very broad domain of competence domains and/or make sure that accident investigation teams together represent a broad scope of competence areas. These issues have a parallel in various factors that could be responsible for accident causation in themselves: for example, technical design issues are often in need of a broad competence to make sure that relevant aspects of the design are addressed at an early stage.

5.1.2. Resources for conducting the investigation – what you fix depends on what you can afford to investigate

Investigators in the road and nuclear domains mentioned that resources were sometimes unavailable. Time was mentioned as one factor, and another was that many investigations were simply not done at all, that ought to have been done.

“We are supposed to do about seven extended investigation per year in our region. But it's questionable whether we can achieve that, and it's also a question of resources.” (Excerpt from interview)

As was found in a previous study (Rollenhagen *et al.*, 2010) the time invested in specific accident investigations may be rather limited due to resource constraints. Personnel that spend most of their time doing other things than investigating accidents perform many accident investigations as part time duties.

5.1.3. Availability of data for investigation – what you fix depends on what you can find

People not talking to the investigator. In the road, rail, nuclear, and maritime accidents sectors, the investigators mentioned that people sometimes were not available to talk to the investigator, resulting in missing data. One factor making people unavailable was the law, making it voluntary to talk to investigators. Another factor was the own organizational limit. Outside the own organization, people would not be required to cooperate (road, rail), and in other cases contract workers may not be found (nuclear), or the organization involved might have ceased to exist, for instance a wharf (maritime accidents). Another factor was that “dead people do not talk”, which is a specific problem for road accident investigations that mainly concerned accidents with death as the outcome (road). A less severe factor was that people might not volunteer answers, unless asked specific questions.

"We have constraints in our investigation work, we for instance do not have a mandate to talk to the driver. If he doesn't want to talk to us then he can tell us to go away" (excerpt from interview in the rail domain)

Some places cannot be visited. It was mentioned in the nuclear domain that you sometimes couldn't enter some parts of the nuclear plant while it is running.

Other actors sharing data. It was common in the road domain to mention that other actors often willingly shared data needed for the investigation. They could get data from the police (photos), the rescue services, from the medical examination of the dead, or from the manufacturer of the car to read the black box.

Availability of data is of course also a factor that can cause accidents in itself. Failures to abstract relevant data can be a causal factor that influences human behavior in terms of limited mental models in coping with hazardous processes.

5.1.4. Political considerations affecting investigation – what you fix depends on what you dare to find

Investigators mentioned that management was not always happy about criticism, which was a problem for examining management as a cause of accidents.

"Informant: It has happened twice that management has asked me to visit their office. And I have been told that the investigation is flawed and that this and that should be changed.

Interviewer: But you didn't do that?

Informant: No

Interviewer: So did they learn from what you wrote?

Informant: No, I wouldn't say that they did, the investigation was flawed" (excerpt from interview)

The parallel to accident causation patterns is obvious: political issues including various aspects of morality, failures to adhere to criticism about decisions etc. has been found as being influences behind many large scale accidents (e.g. Columbia and Challenger).

5.1.5. Transition from analysis to design – what you are able to fix depends on what you find

Finding an appropriate rule to govern the decision to halt causal search is a much-discussed subject in the context of accident investigation. Some examples of how this issue appears in the material are given below:

Stop-rule.

- There is no stop-rule, you use your feel for it (rail)

- When you feel emptied, then it's done (work, patient safety).
- When all the facts have been ticked-off then the analysis is finished (maritime accidents).
- When the facts and event chain is described, then the analysis is self-evident (maritime accidents).
- When you can formulate remedial actions, then it's done (nuclear, work, patient safety)
Example: when you have reached the level of violations against laws, then it's done (work)
- Factors that are about three steps up from the event are what you try to find remedies for (nuclear)
- The analysis stops at about five causes to fix, since it is usually possible to deal with, whereas twenty would be impractical to fix (patient safety).

5.2. *Practical considerations during design of remedial actions*

5.2.1. *Competences needed for design – what you know how to fix is what you fix*

A special case of “what you find is what you fix” is “what you know how to fix is what you fix”. Investigators from the road and nuclear domains pointed out that some causes have known remedies. In the maritime accidents domain, one investigator pointed out that from the list of factors in the investigation, one picks the ones that can be remedied.

Specialists and teams. Several investigators mentioned using teams, both of other investigators and experts. For instance, other investigators could go through the factors found, checking whether something has been overlooked as cause and as remedy (road, maritime accidents). Specialists were also seen as useful (nuclear, rail, work), for instance to make specific solutions (work). One respondent from the nuclear domain suggested that it would be desirable to have a team with people from the analysis group, a dedicated team for making recommendations, and people from the recipient organization as well as expertise from the problem area. The investigator thought that this would increase the likelihood for recommendations that can be implemented.

People familiar with the situation. Investigators from the patient safety domain thought that people familiar with the situation were important to involve. They pointed out that the team leader from the recipient organization is necessary to understand the practice, and is also one who would be involved in implementation. Moreover, the people interviewed during data collection area are also asked for ideas about remedial actions, which are later often used.

“The remedial actions have often emerged from our interviews. We always ask the people we interview ‘what remedial action would you propose to prevent this?’” (Excerpt from interview in the patient safety domain)

Of course, it might at first sight seem a rational idea to actually fix what you know how to fix but it can also lead to a hesitation to refrain from more complicated (but not yet known) possible strategies that may solve the problems. The parallel to accident causation factors is situations in which an organization continues to address safety problems with the same means although they have been proven to be ineffective.

The phase of remedial actions is a much-neglected issue in accident investigation (Lundberg et al. 2009). This is somewhat surprisingly in consideration of those efforts that usually are devoted to design issues in general. Since the result of a causal analysis in accident investigations

normally result in a set of recommendations – why should this phase, as being perceived in the context of accident investigation, be so different from other contexts involving design issues?

5.2.2. What you fix depends on what you find

Several investigators thought that the analysis gives the right remedies (maritime accidents, rail, work, patient safety, road, nuclear). In the nuclear domain, one investigator pointed out that “root causes” are fixed, and in the patient safety domain it was pointed out that “direct causes” often already had been fixed when the investigation started.

Risks do not affect what you fix. In the maritime accidents, rail, road, and patient safety domains, investigators thought that new risks are not systematically considered. However, in the maritime accidents and rail domains investigators pointed out that risks were nevertheless considered but in a less systematic ways. In the work domain, an investigator pointed out that the recipient of the recommendation should perform risk analysis.

Complexity and unforeseen consequences. Investigators in the road and rail domains pointed out that risks are sometimes hard to judge. For instance when removing a dangerous crossing, people might cross anyway, and then in an even more dangerous way than before (rail).

“People do not look out for themselves at road crossings.” (Excerpt from interview in the road domain)

Being able to foresee harmful side effects of decisions is an important factor to consider in safety management. Many accidents have been influenced by failures to perceive side effects of changes in technology and organizations. The result of accident investigations has sometimes been accused of being too naïve in terms of suggesting remedial actions that increases complexity rather than reducing it. Producing “more of the same” in terms of procedures, warnings, controls etc. are not necessarily the best way to cope with complexity.

5.2.3. What you fix depends on what you are going to fix

In the nuclear domain, one investigator thought that it is a risk that fixes are already being considered when analysis begins, so that data collection aims at the preconceived fixes. The investigator thought it might be possible to prevent if another group takes over after analysis.

This view, although only mentioned by one informant, corresponds to the well-known confirmation bias (Johnson, 2003).

5.2.4. What you fix depends on what someone else decides

Decision about what to implement. In the road, nuclear and patient safety domains, investigators mentioned that someone else decides what, if any, of the recommendations to implement.

“There can be numerous suggestions for remedial actions, for instance closing a road, lowering the speed limit, or move an entrance... those kinds of things. And either all of them are implemented, or maybe some of them are implemented, or maybe nothing. That's not our decision to make”. (Excerpt from interview in the road domain)

Handling uncertainty at the source is often an effective strategy in safety management. People familiar with the uncertainties and the context surrounding a specific application domain are usually better than others in suggesting what can be done to cope with local problems. On the other hand, being too familiar and “involved” may increase the risk of not seeing how processes extend over several local application domains (both vertically and horizontally). A balanced safety management approach would be one that recognizes both the need to handle uncertainty locally but at the same time address problems in need of a broader systemic thinking. A possible

solution, then, would be to organize the remedial action phase in terms of a specific group of people that contain both the accident analysis team members and others that have not been involved in the investigation.

Items not supported by rules. Investigators from the work and maritime accidents domains made suggestions of items that were not required by law. Especially for organizations that prioritize safety, since they are more likely to implement them.

Least effort. In the nuclear domain, one investigator explained that fewer recommendations are made now than before, to avoid that only the ones that demand the least effort are implemented.

5.2.5. What you fix depends on what is possible

The organizational limit. In the nuclear and rail domains, investigators thought that it is pointless to go after factors outside the own organization. People in other organizations do not have to listen to the recommendations (rail). Instead, to deal with problems beyond organizational limits one has to work with the own quality control (nuclear).

"We do not have the mandate to tell them to educate their personnel better" (excerpt from interview in the road domain)

International context. In the maritime accidents domain, investigators pointed out that ships could change flags if a rule becomes too restrictive. Therefore, some rule questions must be decided internationally, for instance to demand the use of a maritime pilot on a 2-watch ship, or the decision not to allow 2-watch ships at all.

To stay within own organizational boundaries in the analysis of risk and safety is a well-known risk factor that may induce complacency and a factor known to have had influence in accident causation. If such a negative influence supports less adaptive accident investigation practices it need to be changed. The problem here is partly one about setting up effective communication networks from an organization to stakeholders outside the organizational boundary.

5.2.6. What you fix depends on who you are

Different systems, different safety levels. Passenger ships and small fishing levels do not get the same safety demands, one investigator in the maritime accidents domain pointed out.

- Pointless fixes are not suggested

In the maritime accidents and work domains, investigators said that pointless items are not demanded, such as demanding that people do not fall asleep or change their attitudes.

- Difficult fixes are not suggested

In the road domain, one investigator noted that it is hard to build away risks when people go outside the limits of the system. Other factors that make some causes intractable to fix have been reported, for instance regarding the road domain (Elvik, 2010).

"Those mistakes that are made on purpose... those who go outside the system on purpose... those are of course hard to build away. They are trying to go outside the system limits. So I mean, maybe then one needs a system with barriers that prevents people from going outside of the limits. Then maybe one needs to address the vehicle. So that it's impossible to go faster than the speed limit. So that one can't play with the vehicle. But then that's unrealistic." (Excerpt from interview in the road domain)

- The particular place is fixed

In the road and rail domains, investigators noted that some other place is might actually be more dangerous than the scene of the accident, but the place where the accident happened is the one remedied.

“If you look at this (name of place removed), then it was decided to place motion detectors here. (The informant is referring to a previous explanation of an accident at a railway crossing) We had that part, but one can consider whether it is the right crossing to remedy. Perhaps it would have been more effective at a crossing over there? But nothing has happened there yet. But it has happened here so it is placed here. But what are the chances that it happens here again? Maybe next time it’s over there, so it would have been better there because the risk is higher over there. We consider those issues but sometimes we don’t get our way.” (Excerpt from interview in the rail domain)

5.2.7. What you fix depends on the cost-benefit balance

Some investigators in the rail, maritime accidents, patient safety, and road domains thought that economy was not taken into account by the investigator. However, others presented numerous examples of cost-benefit situations:

- Some things are feared, e.g. wildlife accidents, but does not cause so many deaths and are expensive to remedy (road).
- It is too expensive and slow to work with behavior and education in a sector with such a diverse and huge population (road).
- Sometimes, a less expensive remedy is used while waiting for economy to allow better remedies (patient safety)
- Recommendations cover both expensive and inexpensive alternative remedies (patient safety)
- One can’t always pick the most expensive remedy, if there are too many places that would need it (rail)
- Economy makes routines more common as recommendation than recommending to buy expensive gear (patient safety)
- It’s easy to get money to remedy costly accidents (rail)
- There is no explicit cost limit, but for instance running the plant at lower capacity or building a new reactor tank is considered unreasonable to suggest (nuclear).
- Economic consequences for society should have been thought about for each regulation, but in practice that is not the case. Therefore, if there is a diffuse risk like noise and a small company that may be forced to move, then one thinks about that. But not for risks like losing a finger, that are also usually less expensive (work)
- A price tag is needed, so that the clinic can judge cost-benefit against their tight budget - if it is too expensive then it will not be implemented (patient safety)
- Sometimes, a less expensive remedy is used, waiting for a planned major overhaul (road)
- Some things are very resource demanding, and even if the resources are spent the problem might still not have been fixed (nuclear)

5.2.8. What you fix depends on what is easy to understand and known to work

The investigators mention several quality criteria for remedial actions. The two main criteria mentioned were that remedial actions should be understandable by the recipient, and be effective.

- *Understandable.* It must be possible to understand the recommendation, many investigators thought (maritime accidents, work, patient safety, rail, nuclear). In the work and patient safety domains, investigators thought that “understandable” was not a fixed thing, but depended on the recipient. They thought that in organizations with lower degree of safety thinking, it is harder to make explanations. The patient safety domain thought that the amount of detail was important. For instance, not “more education”, but “more education about X, drivers license for X”. In the nuclear and rail domains they thought that vague formulations should be avoided, such as X should work towards Y. One investigator in the nuclear domain thought that if it can’t be followed up then it is too vague.

“If it (safety) is on a low level, then it is harder to talk to people, they simply do not understand what one talks about. And then one really has to use ones pedagogical skills, one has to teach the company a lot. So that they understand that it is important” (excerpt from interview in the work domain)

- *Effective.* Although one investigator explicitly said that no rating about effectiveness was made, other had different experiences. For instance, some kinds of recommendations were seen as ineffective, with effects that wear off with time (nuclear). PM:s were seen as weak (patient safety), but rules about enforcement of barriers can be very effective against physical damages (work). In one domain, a checklist was mentioned as part of their method to assess effectiveness (patient safety).
- *Tested.* The remedial action should be tested on a smaller scale, since change does not always equal improvement (patient safety).
- *Measurable.* It should be possible to measure the recommendation (road) It can be hard to measure the effect of recommendations, for instance the effect of the new executive safety policy (work). When possible the effects of implementing recommendations should be measurable, but it’s not always possible in practice (patient safety).
- *Reliance on rules.* The recommendations must be backed up by rules, and sometimes the rules must be changed (maritime accidents).
- *More accidents VS less severe accidents.* Sometimes remedies are made that cause more accidents, but less severe ones (road).
- *Implementation plan / Tangibility.* It should be clear when the remedy should have been implemented, who the responsible party is, and money should be allocated (rail)
- *Cost.* There should be an approximate cost statement of the remedial action (medical)
- *Acceptable.* The remedial action should be acceptable by the target organization (medical)

6. Summary – what you find is not always what you fix

Investigators do mention their investigations follow the ideal, *what you find is what you fix*. However, the data suggests that analysis and design of remedial actions both are influenced by constraints. This affects how accident model and factors are practically employed in an investigation. The influence of constraints on the design of remedial actions indicates that *what you find is not always what you fix*. There seems to be several variations of deviations from the ideal, related to constraints:

- What you can fix depends on what you are able to understand (experience of the practice that is under investigation, general investigation experience)
- What you fix depends on what you can afford to investigate (unavailable resources)
- What you fix depends on what you can find (people not talking to the investigator, some places cannot be visited, other actors sharing data)
- What you fix depends on what you dare to find (management resistance)
- What you are able to fix depends on what you find (the stop-rule for analysis)
- What you fix depends on what you know how to fix (specialists and teams, people familiar with the situation)
- What you fix depends on what you find (risk do not affect what you fix, complexity and unforeseen consequences)
- What you fix depends on what you are going to fix (confirmation bias)
- What you fix depends on what someone else decides (decision about what to implement, items not supported by rules, least effort)
- What you fix depends on what is possible (the organizational limit, international context)
- What you fix depends on who you are (pointless fixes are not suggested, difficult fixes are not suggested, the particular place is fixed)
- What you fix depends on the cost-benefit balance
- What you fix depends on what is easy to understand and known to work (understandable, effective, tested, measurable, reliance on rules, more accidents vs. less severe accidents, implementation plan / tangibility, cost, acceptability)

The constraints found in this study, and the respective principles, were specific for the 22 investigators and their experiences of investigation practice in their various domains. Thus, other investigators and other practices may work by different principles. However, it is likely that also other practices and practitioners are led away from the ideal of what you find is what you fix – be it by the same constraints found in this study, or by other constraints.

In accident investigation research, and also investigation methods development, we have observed a tendency to create more thorough and complete investigation methods. Although that is in general a good thing, it is unlikely to prevent most of the factors mentioned by the investigators from leading the investigation away from the ideal of what-you-find-is-what-you-fix. One reason for that is that some factors are out of control of most investigators, such as their resources for investigation, international rules, and their reach of recommendations. Poor investigation methods were not mentioned as something interfering with investigations. Many investigators on the contrary expressed that they were satisfied with their investigation manuals and the methods suggested there.

Availability of data can be a major limitation to what accident model and what factors that can be considered in specific domains. This can be seen as a property of the domain, or as a property of the current system of investigation, including resources for investigation, rules for what to investigate, and laws that allow or forbid certain data to be perused. Road traffic is instructive with regards to this aspect. The accident scene is usually readily available, including vehicle, and surroundings, creating a bias towards the scene of the accident and the accident event. Strengthening this bias is the lack of data regarding more remote events, such as phone calls (mobile traffic data unavailable), or motives and previous events during the trip (since the driver

is dead, a condition for initiating the investigation). Road traffic is (compared to controlling a nuclear power plant) relatively linear and tightly coupled, making it a potentially tractable system. Nevertheless, unavailable data makes it less tractable with respect to events preceding the immediate accident event.

Finally, the stopping rule for analysis appears to be the level of preventable causes - which are influenced by practical constraints regarding reach, this is embodied in the deviation “what you find is what you can fix”. The level of preventable causes varies between organizations, depending on their reach. This arguably is a critical level to address, when aiming at preventing future accidents. However, it also limits the value of the analysis to look at a bigger picture. If analysis does not go further than what can now be addressed by recommendations, then it provides little guidance about what critical factors that might now be out of reach - but which might need to be addressed in the future.

Many of the constraints found in this study are not primarily “cognitive” in nature, they do not reflect flawed thinking, which is the basis of some well-known biases (e.g. Johnson, 2003). One exception was “confirmation bias”. In addition to cognitive biases, many of the constraints found here more closely resemble those that are in play in organizational accidents. Some clearly are political in nature, for instance cost-benefit decisions, just like some of the constraints presented by Johnson (2003).

7. Conclusions

We conclude that there are many factors that can draw an accident investigation away from the ideal principle of what-you-find-is-what-you-fix. That principle is clearly the ideal in many Swedish investigation manuals (Lundberg *et al.*, 2009). Nevertheless, factors both in the analysis and data collection phases, the transition to design of remedial actions, and during the design of remedial actions, drive investigations towards other principles. We also conclude that the holy grail of research, of more complete and thorough investigation methods are unlikely to help to counter most of the factors mentioned by the experienced accident investigations in this study. Instead, research must aim at methods and tools that specifically address issues caused by constraints in the investigation process, in the transition from analysis to design of remedial actions, and the design of remedial actions. Moreover, the limited scope of investigation of causes to those that are preventable can be a source of bias in examining a “bigger picture” of causes of accidents at large – which becomes limited to those causes that are currently seen as fixable by investigators.

Accident investigation is not a rational process. Neither is the choice and implementation of remedial actions. Or perhaps one should argue that it actually is rational – in a pragmatic sense – to consider the possibilities and constraints of the situation where safety takes place. This means that some of the ‘fixes’ are reasonable from a practical point of view, while others are unreasonable. The bottom line must be a warning against believing in the rationality – but not the sensibility – of investigation and re-mediation.

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Appendix: Interview guide

Background information

- 1.1. Which are your main duties at this particular administration?
- 1.1.a. How long have you worked here?
- 1.1.b. Do you work full-time or in parallel with other work, assignments?
- 1.2. How long have you worked as investigator?
- 1.2.a. How many investigations have you taken part of or been responsible for?
- 1.2.b. Which industries have you worked for (or which types of accidents have you investigated)? For how long?
- 1.3. What are your qualifications for this position? (E.g. education, practice.)
- 1.4. Are you active in a broader context where investigative issues are debated? (E.g. problems, strategies, manuals, regular meetings, mailing lists.)
- 1.5. Which is, according to your opinion, the primary reason for incidents and accidents within (name of transport sector)? Why?

Information about the phases of an investigation

- 2.1. Which is the principal aim with investigations of incidents and accidents?
- 2.2. How many persons are usually involved in an investigation?
Could you say anything specific about the analyzing activities? (E.g. planning, data analysis, modeling, recommendations, implementations, evaluations.)
- 2.3. What type of support do you receive for every activity? (E.g. time, team, competence.)
- 2.4. What ‘breaks off’ or puts an end to the analytical phase and initiates the formulation of necessary measures?
- 2.5. Can you give a little more detailed description of how you work when specifying measures?
- 2.6. Do you usually estimate the efficiency of various measures? If so, how?
- 2.7. How should measures be formulated?
- 2.7.a. How important is it that the addressed organization accepts the proposed measures?
- 2.7.b. How do you work with addressed organizations’ acceptance of measures?
- 2.7.c. How do you work with the adjustment cost-benefit? How is this adjustment assessed?
- 2.8. Measures tend to bring about new risks. Is it possible to estimate

these risks in regard to the propositions that you give?

- 2.9. How do you work with measures that are to be implemented?
- 2.10. What is your opinion on follow-ups of measures?
- 2.11. How do you practically follow up measures? (If possible, relate to a case that the informant has worked with.)
- 2.12. Can you exemplify how measures have been followed up? (Alternative: How these measures will be followed up?)

Information about professional investigative manuals

- 3.1. There is a material (name/title), which describes your work with investigations. Have you taken part of this text?
- 3.2. How could such a material be used? (E.g. education, reference material, competence development.)
N.B. Question 3.3. – 3.7. for those who actually have read the material.
- 3.3. How often do you use the manual?
- 3.4. For which phases of the investigative work is the manual useful?
- 3.5. Is anything missing in the manual? What?
- 3.6. How could the manual be improved?
- 3.7. Do you usually follow the manual's recommendations?

Information about accident models

- 4.1. When an accident is analyzed, to what extent is the accident's course of events investigated in comparison with the activity as a whole?
- 4.2. In the case of given or assumed causes, how do you decide which causes that need to be followed up – and how far is this work taken? Are there directions for this?
- 4.3. How do you look upon single traces, in comparison with several traces or causes?
- 4.4.* When it comes to whole activities and situations, how do you investigate:
 - 4.4.a.* - the management and control of an organization?
 - 4.4.b.* - factors outside an organization, for example, manufacturers, authorities, other actors?
- 4.5. In order to prevent future accidents of the same type as (x), should one focus events that are close to the accident in time and space or more environmental factors?
- 4.6. How should, according to your professional view, stability and resilience be balanced? In other words, are we in need of stronger rules and norms – or more flexibility?
 - 4.6.a. Exemplify with a case.
- 4.7. Relate measures to a case.

Safety culture

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- 4.8. Attitudes towards safety are considered to be a factor, which prevents accidents. How do you work with attitudes when forming measures?
 - 4.9. Sectors where people pass, for example, the transport sector or institutional care, have numerous visitors (not only staff). What is your opinion on working with attitudes and rules in such context?
 - 4.10. Which factors should be considered when the safety of an activity is to be analyzed?
 - 4.10.a. Do you consider sector (x) to be safe for stay and work?
 - 4.11. How can we know that an activity is unsafe? Are there any particular indicators?
 - 4.12. Using your perspective and experience, is it possible to analyse such indicators?
 - 4.13. What is your opinion on safety culture and safety climate?
 - 4.14. How are the concepts safety culture and safety climate used in connection with accidents that you investigate?
 - 4.15. Organizations differ as regards their safety thinking. Does this fact have any impact on your investigative work?
 - 4.15.a. Is it possible to somehow adjust measures to safety levels?
 - 4.16. It is, on the whole, possible to get a fair picture of an organization's safety level in connection with an accident?
 - 4.17. Is it possible to influence organizations' safety levels with measures?
 - 4.18. What is the relation between the management of an organization and safety standards? It is possible to influence the management in any way?
 - 4.19. There are sometimes reasons to believe that accidents could have been prevented through different safety systems, for example, incidence reports, accidents investigations, and descriptions of safety work. What could be said about measures and analyses in these contexts?
 - 5.0. Conclusive comments (if any).

References

- Elvik, R., 2010. Why some road safety problems are more difficult to solve than others. *Accid. Anal. Prev.* 42 (4), 1089-1096.
- Factor, R., Mahalel, D., Yair, G., 2007. The social accident: A theoretical model and a research agenda for studying the influence of social and cultural characteristics on motor vehicle accidents. *Accid. Anal. Prev.* 39 (5), 914-921.
- Gordon, J.E., 1949. The epidemiology of accidents. *Am. J. Public Health* 39 (4), 504-515.
- Heinrich, H.W., 1931. *Industrial accident prevention: A scientific approach*, 1 ed. McGraw-Hill, New York.
- Heinrich, H.W., 1934. The accident sequence. *Safety Talks* (November 30th), 1-5.

- Hollnagel, E., 2004. Barriers and accident prevention. Ashgate, Burlington, VT
- Johnson, C.W., 2003. Failure in safety-critical systems: A handbook of accident and incident reporting. University of Glasgow Press, Glasgow, Scotland.
- Kjellén, U., 2000. Prevention of accidents through experience feedback. Taylor & Francis, London.
- Knox, N.W., Eicher, R.W., 1992. Mort user's manual for use with the management oversight and risk tree analytical logic diagram. System Safety Development Center, Idaho National Engineering Laboratory Idaho Falls, Idaho.
- Korolija, N., Lundberg, J., 2010. Speaking of human factors: Emergent meanings in interviews with professional accident investigators. *Saf. Sci.* 48 (2), 157-165.
- Lehto, M., Salvendy, G., 1991. Models of accident causation and their application: Review and reappraisal. *J. Eng. Technol. Manage.* 8 (2), 173-205.
- Leveson, N., 2004. A new accident model for engineering safer systems. *Saf. Sci.* 42, 237-270.
- Lundberg, J., Johansson, B., 2006. Resilience, stability and requisite interpretation in accident investigations. In: *Proceedings of the 2nd Symposium on Resilience Engineering*, Juan-les-Pins, France, pp. 191-198.
- Lundberg, J., Rollenhagen, C., Hollnagel, E., 2009. What-you-look-for-is-what-you-find - the consequences of underlying accident models in eight accident investigation manuals. *Saf. Sci.* 47 (10), 1297-1311.
- Reason, J., 1997. Managing the risks of organizational accidents. Ashgate, Burlington, VT.
- Rollenhagen, C., 2005. *Säkerhetskultur*. RX media, Stockholm.
- Rollenhagen, C., J. W., Lundberg, J., Hollnagel, E., 2010. The context and habits of accident investigation practices: A study of 108 swedish investigators. *Saf. Sci.* 48 (7), 859-867.
- Santos-Reyes, J., Beard, A.N., 2009. A systemic analysis of the edge hill railway accident. *Accid. Anal. Prev.* 41 (6), 1133-1144.
- Sklet, S., 2004. Comparison of some selected methods for accident investigation. *J. Hazard. Mater.* 111 (1-3), 29-37.
- Svenson, O., 1991. The accident evolution and barrier function (aeb) model applied to incident analysis in the processing industries. *Risk Anal.* 11 (3), 499-507.
- Svenson, O., Lekberg, A., Johansson, A.E.L., 1999. On perspective, expertise and differences in accident analyses: Arguments for a multidisciplinary integrated approach. *Ergo* 42 (11), 1561 - 1571.
- Woodcock, K., 1995. Bias in real-world accident cause-finding. In: Bittner, A.C., Champney, P. eds. *Advances in industrial ergonomics and safety*. Taylor & Francis, London, pp. 907-914.