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# Prerequisites for learning from accident investigations – A cross-country comparison of national accident investigation boards

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**Abstract:** In this paper railway accident investigation reports issued by the national accident investigation boards in three Scandinavian countries during a 2-year period have been systematically studied. Content analysis of attributed causes in these reports reveals a considerable emphasis on physical processes, actor activities and equipment (the microlevel). Much less attention is paid to organisational factors (the mesolevel) and conditions related to regulators, associations and government (the macrolevel). This means that lessons will primarily be learned about aspects at the lower of these levels. Interviews show that the factors emphasised in investigation reports typically reflect the competences and experiences of the investigators, i.e. they are inclined to focus on areas of their own expertise. Since failures at the microlevel in many cases merely are symptoms of trouble at higher levels, it is argued that competence among investigators that supplements entirely technical or operational backgrounds are necessary for enabling deeper understanding of the factors leading to accidents. One possible way for achieving this is the creation of multi-modal investigation boards that provide a number of potential advantages, such as increased access to specialist competences that are shared between different sectors. Although a multi-modal approach to some degree has been adopted in all three countries, interviews reveal that these positive effects do not emerge automatically. It can therefore be concluded that multi-modal investigation boards offer a number of possible advantages, but only when these synergies are fully exploited can they provide a potential for more effective learning from accidents.

**Keywords:** Accident investigations, Investigation boards, Learning, Multi-modal, Railway

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## 1. INTRODUCTION

In the aftermath of accidents numerous questions are raised regarding what happened and why, and how to avoid the same thing from happening again. In order to find answers to these questions, accident investigations are often carried out as a means to reveal what circumstances that paved the way for the mishap to occur. Although several objectives of accident investigations are possible, such as assigning blame or reassuring the confidence in a sector, the primary aim of accident investigations is to learn from the accident in order to prevent recurrence. Furthermore, learning from past events is one of the central characteristics for achieving a more resilient system (Cook & Woods, 2006). However, learning from accidents is not straightforward, and the overall aim of this study is therefore to contribute insights regarding what aspects that have an effect on the ability for effective learning. The search for lessons to be learned after an accident is influenced by a number of factors. For example, depending on the framing of an event different ways of “reconstructing the truth” from the abundance of clues that can be found on the accident scene are possible (Catino, 2008). This means that although investigators typically look at events and conditions both in the close proximity (spatially and temporally) of the accident scene, and on more remote factors (the “sharp end” and “blunt end”, respectively), there are generally no guiding criteria for how far away in space and time from the top event to look (Leveson, 2004). Consequently, the answer as to why a specific event occurred can always be followed by yet another “why”, since it is possible (at least theoretically) to find an infinite number of causes to an accident (Freitag and Hale, 1997). Rasmussen (1990) describes three pragmatic stop-rules for when the search for additional causes typically is terminated;

- 1) When information is missing and the causal path therefore no longer can be followed, or,
- 2) When a familiar, abnormal event is found to be a reasonable explanation, or,
- 3) When a cure is available.

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This arbitrariness in the choice of stop-rules (cf. Leveson, 2004) means that the causes that are emphasised in an accident investigation to a large extent are influenced by the underlying assumptions about how accidents happen. These assumptions that direct investigators to look at certain aspects, but not so much on others, are often implicitly derived both from each investigator's understanding about accident causation, and from the method that is adopted by the investigator, which is described by Hollnagel (2008) as the WYLFIFYF principle; What-You-Look-For-Is-What-You-Find (see also Rasmussen, 1990).

Assumptions about how accidents happen can be described both with regards to conceptions about the scope of investigation, i.e. what factors that should be attributed as the "cause(s)", such as human error or technological failures, and conceptions about the accident model, i.e. the view on how different factors interacted in ways that eventually led to the bad outcome. Historically, a shift of focus has gradually occurred in the research literature regarding the scope of accident causation, moving from technological failures to human error, and later to organisational factors (ESReDA, 2009). This shift of focus has gone hand in hand with the development of accident models, which have contributed with new perspectives on causality, evolving from linear to more complex interactions (Hollnagel, 2004). However, Lundberg et al. (2009) accentuate the need to distinguish between the accident model and the scope of the investigation:

"The two aspects, accident models and scope, are often described together and have historically often changed in parallel. However, it is important to separate the two since the outcome of an analysis in practice will depend not only on the view on causality (i.e., views about the accident "mechanism"), but also on what kinds of factors are included as causes and contributing factors."

Even if both of these aspects are influential for the outcome of an investigation, the focus of this paper will be on the latter of them, i.e. the scope of accident investigations. Since those aspects of an accident that are emphasised in the investigation report influences what lessons can be learned it is interesting to study what aspects that gain most attention in investigation reports. Therefore, the first part of this paper aims at answering how much attention that different factors described as contributory to accidents gain in accident investigation reports issued by the national investigation boards in three Scandinavian countries. In addition, a comparison of these three countries provides an opportunity to identify factors that are more or less beneficial for the potential to learn from accidents. The second part of this paper therefore aims at answering what characteristics of the investigation boards that can be identified as influential for the ability for effective learning from accident investigations.

The three Scandinavian investigation boards included in this study will be denoted A, B and C. All of them are permanent and independent national accident investigation boards characterised by a similar purpose of investigation (preventing a recurrence of the accident or incident without assigning blame), but with different structures and mandates. Investigation board A (with 22 employees in total) has the broadest mandate, encompassing a wide range of different types of serious accidents. In addition to transport accidents (aviation, railway, maritime and road traffic accidents), this investigation board also investigates other types of serious accidents including military accidents, mining accidents and accidents involving nuclear or chemical activities. Investigation board A was established in 1978 and has had its present responsibility since 1990, which means that it has the longest tradition of a multi-modal structure (i.e. investigation of accidents and incident in more than one sector) of the three studied investigation boards. Investigation board B (with 40 employees) was established in 1989 with a responsibility for investigating aviation accidents. In recent years it has been expanded to also include investigation of railway accidents (since 2002), road traffic accidents (since 2005), and maritime accidents (since 2008). Investigation board C (with 14 employees in total) was established in 1979 with a responsibility for aviation accidents. Since 2004 this investigation board also investigates railway accidents.

The three Scandinavian countries have many societal similarities, but the investigation boards have somewhat different structures, traditions and work processes, which make a cross-country comparison interesting. These differences in structure and other characteristics can be found among national

investigation boards in other countries as well, which means that the results from a comparison of these features are valuable also for countries outside of Scandinavia. In particular the results are interesting for other EU member states, since they share the same obligation for establishing an independent investigation board for investigation of railway accidents and incidents according to the Railway Safety Directive (2004/49/EC), but with some differences in the way that this directive is implemented nationally.

## 2. METHOD AND MATERIAL

The first part of this paper aims at studying what kind of aspects that gain most attention in accident investigation reports. In order to do this, the attributed causes of a number of investigation reports have been analysed. The studied material consisted of all railway accident investigation reports that have been issued by the three countries' national accident investigation boards during a two-year period (2008-2009), excluding tram accidents, subway accidents and thematic reports since these types of reports were unique for one or two of the three countries. This means that a total of 35 investigation reports were included in the study; 14 from investigation board A, 13 from investigation board B, and 8 from investigation board C. An overview of the material is presented in Table 2 in Section 3.2. The study was restricted to the "Analysis" section of each report, in which the attributed causes were described.

Although investigation reports are written in a language that aim at avoiding ambiguities, it is assumed that this type of texts, like all other texts, can never be said to have a completely objective, single meaning (Krippendorff, 2004). Consequently, in order to draw inferences regarding what factors that the investigation teams considered important for contributing to the occurrence of the described incidents and accidents, interpretation of the investigation reports was necessary. In this paper, content analysis was used to draw such inferences. Significant for content analysis is to reduce large portions of text to a smaller number of content categories (Weber, 1990), which made it necessary to create criteria and guiding rules in the form of coding instructions for the categorisation of text. The units of text that were coded amounted to individual sentences (except for sentences that included multiple attributed causes, which were divided into more than one coding unit). The reason for this was that smaller segments, i.e. individual words, would be difficult to interpret since the same word can have different meanings dependent on the context, whereas larger portions of text such as whole paragraphs would contain a diversity of information (cf. Weber, 1990).

The first step of the analysis of investigation reports aimed at identifying all sentences that described a "cause", and the second step aimed at categorising these sentences with respect to the kind of aspect of the accident they described (i.e. the scope). In addition to those sentences where causes were explicitly described (e.g. "the cause of the accident was a broken wheel..."), which typically was restricted to a handful "direct" or "underlying" causes in each report, the studied material included a large number of factors that more implicitly were described as contributory to the mishap, all of which will be referred to as "attributed causes" in this paper. Recognising that numerous ways of defining a cause have been discussed in the literature (Einhorn & Hogarth, 1986; Sklet, 2004; Dekker, 2006), a broad definition that was suitable for the purpose of this study was used for identifying these sentences, outlining a cause to an accident or incident as a necessary but in itself insufficient factor leading to the undesired outcome (cf. Reason, 1990). As can be noted from this definition, an essential first step in categorising the attributed causes was to define "the undesired outcome", i.e. the event that was described in each report as the actual incident or accident that led to the initiation of the investigation, which was typically revealed by the title or introduction of each investigation report. Accordingly, sentences related to descriptions of the rescue operation were not included in the analysis, since these actions were not contributory to the occurrence of the incident or accident. In order to facilitate identification of sentences describing attributed causes in the investigation reports, four broad classes representing different views on "necessary but in itself insufficient factors" were specified in the coding instructions. These classes (presented in Section 3.1) were created iteratively after reading all of the material a first time, and should primarily be seen as an aid for a

consistent identification of sentences to include in the analysis and for subsequent test of inter-coder reliability.

It is important to recognise that the interest of the coder naturally influences the design of the categories created in the coding instructions (Weber, 1990). This means that other ways of coding the material than the approach adopted in this paper would be possible as well, based on different aims and foci of attention. Since the aim of this paper was to identify all factors that were described as contributory to the investigated incidents or accidents, the categories had to be broad enough to be able to capture a large variety of factors, ranging from the actions taken by individual operators to decisions by associations and governments. In addition, several authors have recognised that accidents do not only stem from component failures or deviances, but can also stem from non-linear interactions of factors at different levels of the socio-technical system, despite the fact that none of these parts actually failed or behaved unexpectedly. By adopting this perspective, based on systems thinking (see e.g. Leveson, 2011), it was not sufficient to include only those sentences describing deviances and deficiencies. Rather, the categories created for the coding instructions also needed to include descriptions of factors that were not deviating from some more or less explicit standard but still were described in the investigation reports as contributory to the incident or accident. These requirements lead to the creation of the classes that were used for identification of attributed causes (presented in Section 3.1).

Following the creation of the final coding instructions the coding of the material was carried out by one of the authors at least two times for each report in order to enable evaluation of the stability in the categorisation (Krippendorff, 2004; Weber, 1990). Reliability tests were also carried out for the inter-coder agreement, and the results from these tests are presented in Section 3.3. As several reports from each country were included in the study, it is argued that differences between the investigation boards' emphasis regarding factors that were seen as contributory to accidents can be identified regardless of the fact that the reports do not deal with exactly the same type of events (although many similar incidents and accidents are covered).

In addition to the content analysis of investigation reports, the second part of this study consisted of an interview study with investigators from the three countries, which aimed at gaining deeper insights of their practices and work processes. Semi-structured interviews lasting between 1 h and 45 min and 2 h and 15 min were carried out with two representatives from each of the three investigation boards. The interviews were carried out at the investigation boards' facilities and the questions that formed the basis for the interviews were distributed in advance. The recorded interviews were transcribed and the transcriptions were analysed by marking factors that were described by the interviewees as influential for the outcome from accident investigations, and in particular for the potential to learn from accidents. The results from this work are presented in Section 3.4. A draft version of the finalised paper was distributed to the interviewees in order to allow them to comment on the findings.

## **2.1 Conceptual foundation for categorising the scope of attributed causes**

Rasmussen and Svedung (2000) point out that risk management in our dynamic society involves many nested levels of decision-making. Their representation of a socio-technical system consisting of several hierarchical levels was used as a conceptual starting point for describing where focus of the attributed causes of the studied investigation reports could be found. This way of categorising a socio-technical system based on a number of related levels emphasises that the same event can be seen in different ways depending on the perspective that is adopted. For example, an action by an individual operator can be seen both from that operator's perspective and from a perspective that is highlighting organisational or regulatory aspects influencing the same action. Based on Rasmussen (1997) and Sklet (2004), the following three hierarchical levels were used to categorise the attributed causes that were identified in the studied material, which were labelled in accordance with the suggestion by Le Coze (2008) as the micro, meso and macrolevels, see Table 1.

**Table 1: Three hierarchical levels used for categorising attributed causes**

Hierarchical level	Description
Macrolevel	Regulators, associations and government
Mesolevel	Company and management
Microlevel	Technical base and staff

The highest level (the macrolevel) included factors related to inter-organisational aspects, regulatory bodies, inspectorates, associations and even governments (see Rasmussen and Svedung, 2000). The next level (the mesolevel) included organisational aspects such as management issues and other intra-organisational factors, whereas the lowest level (the microlevel) represented a level that included equipment, actor activities, and physical processes (see Rasmussen and Svedung, 2000). For some instances the categorisation of attributed causes did not relate naturally to these three levels, for example description of information flows, that can be found at all three levels. This was resolved by creating clarifications in the coding instructions with regards to the most appropriate categorisation of such units of text.

### 3. RESULTS

#### 3.1. Specification of classes used in the coding instructions

As mentioned in Section 2, four broad classes representing different views on “necessary but in itself insufficient factors” were specified in the coding instructions after reading all of the material a first time. Each sentence that complied with any one of these classes were categorised with respect to which of the three hierarchical levels (micro, meso or macro) it described. The four classes included the following types of factors:

- 1). Deviations and deficiencies. A deviation or deficiency involved descriptions of events and conditions that contributed to the incident or accident because they departed from expected actions or functions, such as malfunctioning, errors, or deficits. Additionally, this class included actions that either departed from formal rules, regulations and procedures, or from more informal, implicit (and even judgmental) expectations expressed in the reports, including sentences such as “the train driver should have made sure that the brakes were working as intended...”. Sentences that complied with this class can be seen as normative in the sense that they to some extent assumed a desired state or condition that was not achieved or was not available in the given situation.
- 2). Pressure. Pressure involved descriptions of different types of resource constraints, ranging from mental to organisational phenomena that were portrayed as necessary for the accident or incident to occur. This means that a variety of factors such as stress among individual operators, or organisational demands on punctuality and cost-effectiveness were included in this class. The common denominator was an expressed sense of limited resources, such as time or money, which constrained the possible actions or options of a given situation.
- 3). Ambiguities. An ambiguity involved descriptions of unclear or confusing situations that, without being deviations in the sense described in the first class mentioned above, contributed to the occurrence of the accident. This class involved situations and factors such as misunderstandings, misinterpretations or other kinds of uncertainty.
- 4). Variation in context and conditions. This class involved description of factors where nothing actually “went wrong” or deviated from expected functioning, as opposed to the first class described above, but that still were described in the investigation reports as contributory to the occurrence of the incident or accident. Consequently, this class involved descriptions of apparently rational or functional actions or conditions that through interaction with other factors nonetheless resulted in a bad outcome. For example, where the design of equipment at the same time was described as adequate but still contributed to an incident, for example through unexpected interaction with other factors, the sentence was categorised as belonging to this class. In the same way, description of actions that, under the prevailing conditions were described as rational (cf. the local rationality principle, see e.g. Woods & Cook, 1999), but that in hindsight resulted in a mishap, belonged to this class.

Supplementary specifications to these broad classes were included in the coding instructions in order to further operationalise them and distinguish them from one another when more than one class seemed applicable to the same sentence. Following identification of sentences that complied with any one of these four classes, each sentence was categorised as belonging to the micro, meso or macrolevel.

### 3.2. Results from identification of attributed causes

The four classes created in the coding instructions were used for identifying attributed causes in the studied investigation reports. The class “deviances and deficiencies” represented the most frequently identified class, comprising about 75 % of all attributed causes in investigation reports from all three investigation boards. The total number of attributed causes that were identified in the investigation reports is shown in Table 2. As can be noted from this table the investigation reports from the three countries differed considerably in length; reports from investigation board A, B and C had an average of 44, 24, and 13 pages, respectively. The number of units of text, i.e. individual sentences describing an attributed cause, which were identified and categorised subsequently also differed considerably between the countries. Likewise could a significant difference in the median number of attributed causes per report be found, amounting to 78, 33 and 6 for investigation board A, B and C, respectively (see Table 2).

It is important to note that the number of attributed causes that were identified in the investigation reports should be interpreted as a maximum number of different contributory factors. This is due to the fact that all of the identified attributed causes were counted, even if that specific attributed cause had already been described elsewhere in the studied text. Hence, in those reports where some repetition of previously described factors could be found a certain degree of duplications were unavoidable. This was, however, rarely occurring, and is therefore not considered to have influenced the results to any greater extent.

**Table 2: Description of the studied accident investigation reports**

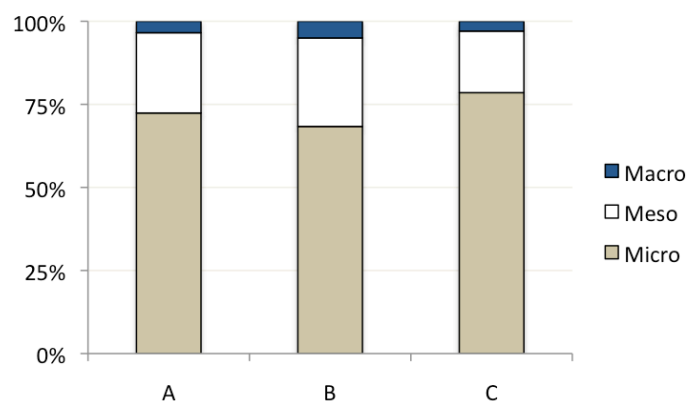
	Investigation board		
	A	B	C
Number of reports <sup>1</sup>	14	13	8
Average number of pages per report (incl. appendices)	44	24	13
Total number of categorised units of text from all reports	1043	398	135
Median number of attributed causes per report	78	33	6

### 3.3. Scope of attributed causes

In order to study what hierarchical level that was emphasised in the reports, the relative number of attributed causes was compared between the countries, i.e. the percentage of the total number of units from each country that were categorised as belonging to the micro, meso and macrolevel, see Fig. 1. The results are presented as the aggregate distribution of all reports, which represented a similar distribution as the median value of investigation reports from each country.

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<sup>1</sup> All investigation reports covering railway accidents that were issued during 2008 and 2009 were selected. Reports covering tram accidents, subway accidents and thematic report were excluded, which means that, in addition to the material included in this study, 2 more reports from investigation board A, 6 from investigation board B, and 1 from investigation board C have been issued during the time period but not included in the material.



**Fig. 1: Relative distribution of attributed causes at the micro, meso and macrolevels**

As can be seen in Fig. 1, a majority of the attributed causes (72%, 68% and 78% in the reports from investigation board A, B and C, respectively) could be found at the microlevel, i.e. describing physical processes, actor activities and equipment, when the aggregate material from each country was compared. This included factors such as component failures, omissions by individual operators and non-compliance with procedures, etc. A smaller fraction of the total number of attributed causes (24%, 27% and 19%, respectively) described factors at the mesolevel, i.e. organisational factors. This included for example provision of safety management systems and related documentation, supply of maintenance and provision of rules and procedures to operating staff. Only a few percent (4%, 5% and 3%, respectively) of all attributed causes could be found on the macrolevel, i.e. describing regulatory aspects or inter-organisational factors. This included lacking or unclear regulations and insufficient coordination between different organisations or authorities, e.g. regarding the allocation of responsibility for safety measures in level crossings. From the results it can be concluded that the relative focus of the reports do not differ to any significant extent. In absolute terms, however, the number of units from the three countries differed significantly, which could be seen in Table 2 above.

In order to test the stability in the categorisation, one of the authors twice conducted coding of the material over approximately 3 months. This resulted in a good agreement. Reliability in the categorisation was also tested by letting a previously uninformed person using the coding instructions and coding approximately one third of the randomly selected reports. The overlap between the two coders was 80% with regards to unitising (i.e. identification of units), and out of these units there was a 96% overlap with regards to coding (i.e. categorisation of units). The degree of inter-coder agreement in the coding was tested by calculating Krippendorff's  $\alpha$ , resulting in a value of 0,95 which indicates a good agreement (see Krippendorff 2004 for a discussion of acceptable levels of agreement).

### **3.4. Results from interviews with representatives from the three accident investigation boards**

The content analysis presented in the previous section was followed up by interviews with representatives from the investigation boards in all three countries. The interviews, together with document studies of annual reports and other documentation aimed at identifying factors that influence the potential for learning from accident investigations. The results will be briefly presented here, and more thoroughly discussed in the next section.

One of the common factors mentioned by all interviewed representatives from the three investigation boards was an alleged shortage of resources. Although the total number of employees of the investigation boards differed between the countries (see Section 1), none of the railway sections of the studied investigation boards consisted of more than four dedicated railway investigators, with predominantly



technical or operational backgrounds. This small number of investigators was referred to as a factor that sometimes made it difficult to finalise investigation reports within the desired time frame of 12 months.

All of the investigation boards have to some extent been merged from separate, smaller investigation boards responsible for investigation of accidents involving one or a few transport modes to investigation of accidents in two or more different sectors. To some extent all of the interviewees showed a positive attitude towards this creation of larger, multi-modal investigation boards, although some of the potential (and sometimes beforehand expected) benefits with merging smaller investigation boards had not yet been fulfilled (which will be further discussed in the next section).

The use of formal accident investigation methods varied considerably between the three investigation boards; from a consistent use of the same investigation method in investigation board A and B to the reference to “no specific method” in investigation board C. Consequently, from the results presented previously in this section, showing a similar relative distribution of attention between the three hierarchical levels in all three countries (as shown in Fig. 1), the distribution of what aspects of an accident that was emphasised did not seem to differ between the investigation boards that used a formal investigation method (STEP, MTO analysis or deviation and barrier analysis), and the investigation board where no such formal method was used. These results indicate that the impact of formal investigation methods on the relative distribution of factors that gain most attention in the investigation reports is limited.

#### **4. ANALYSIS AND DISCUSSION**

In this section, the results from the content analysis and the interview study that were presented in Sections 3.3 and 3.4 are discussed. It should be noted that these two approaches for analysing the work processes and outcome of accident investigations should be compared with some caution, since the interviews were carried out in 2010, whereas the studied investigation reports (that typically took one year or more to finalise) were issued during 2008 and 2009. This means that continuous development of work processes that have occurred in the investigation boards since the point in time when the studied investigation reports were issued are not reflected in the results from the content analysis. In order to more thoroughly examine the effects from different structures and work processes, a longitudinal study would therefore be required where the occurrence of major structural changes of the investigation boards could be compared to the content of investigation reports from different points in time. However, this limitation in the possibility for making a direct comparison of the results from the content analysis and the interview study does not mean that interesting conclusions cannot be drawn. On the contrary, this type of study including more than one type of methodology provides a complementary and richer picture of the area under examination (see e.g. Mingers and Brocklesby, 1997).

The results from the content analysis presented in Sections 3.2 and 3.3 showed that the investigation reports from investigation board C generally were less numerous, shorter, and included a considerably smaller number of attributed causes compared to the other two countries (see Table 2). Although the length of investigation reports and the number of attributed causes do not constitute sufficient indicators of their “quality”, it is crucial to acknowledge that a rich and lengthy description both of the factors contributing to an accident and its context is required in order to gain a deep understanding of the event. As pointed out by for example Cook et al., (overly) simple stories of complex events (referred to as “first stories”) are too limited in details “to serve as the basis for understanding the interplay of the multiple contributors that led to the accident” (1998, p. 11). Rather, they state that detailed investigations (“second stories”) that show “how multiple interacting factors in complex systems can combine to produce systemic vulnerabilities to failure... can point the way to effective learning and system improvements” (Cook et al., 1998: p. 2). Consequently, even though no criteria on a minimum or sufficient number of attributed causes can be defined, these results indicate that the ability to more fully describe the interplay between the large number of factors that generally are necessary for the occurrence of accidents in complex socio-technical systems was more restricted in investigation board C compared to the other countries.

Despite the difference in median numbers of attributed causes in investigation reports from the three countries (as shown in Table 2), a similar relative distribution could be found (see Fig. 1). A majority of these attributed causes related to the microlevel, which included physical processes, actor activities and equipment. All of these factors can be found in the close proximity of the accident scene (i.e. close to the “sharp end”), and are therefore typically among the first things that investigators examine during an investigation. As a result, these factors generally gain considerable attention in the investigation reports. Conditions at the “blunt end” on the other hand are generally more difficult to pinpoint as causes the further away from the accident scene they are found (see Rollenhagen (2011) for further discussion on this topic). This is particularly the case if a viewpoint on accident causation is adopted that predominately focuses on deviances and deficiencies, which for example excludes important factors stemming from non-linear interactions between parts of a system where none of the parts failed or were missing (see Leveson, 2011).

Furthermore, aspects at the microlevel seem to be more familiar to the investigators. As mentioned in Section 3.4, interviews with representatives from the three investigation boards revealed that most (and in one of the countries all) of the investigators have a technical or operational background, such as for example train drivers, technical maintenance staff and traffic management operators, which means that they can be assumed to have less insights and experience from the perspective of a manager or regulator. This indicates that the emphasis in the investigation reports on aspects at the microlevel typically reflects the skills and experiences of the investigators, i.e. that the investigators are inclined to focus on areas of their own expertise.

There is no doubt about the importance for the outcome from accident investigations that at least some of the investigators have deep insights and/or experience from the relevant sector. Lessons learned about aspects at the microlevel, such as insights regarding improvements of technical functions, contribute with important steps towards more robust and reliable systems. For example, major developments in the aviation sector stem from these incremental but important technical design improvements (Leveson, 2002; Stoop, 2002). However, although many microlevel aspects are important contributors to accidents, these factors generally only constitute a limited explanation to the occurrence of a mishap. Consequently, if focus is restricted to aspects at this level, such as failing components, other important aspects including for example organisational factors are missed (Leveson, 2011). Furthermore, it is not sufficient that a meso or macrolevel perspective is provided in the ensuing recommendations, since these proposed remedial actions are not likely to achieve the desired results if the context in which these actions are supposed to be implemented are not analysed in the investigation report. Rather, effective remedial actions require a strong analytical link between the identification of attributed causes and suggested countermeasures.

Lessons learned about aspects at the microlevel that lack consideration of aspects at higher levels are therefore not satisfactory for providing powerful countermeasures aiming at improving the functioning of the system as a whole. For example, identification of a train driver who “did not pay sufficient attention” does not contribute with significant lessons about how to improve safety of the system, since these actions generally are inappropriate only when seen in hindsight (cf. Fischhoff, 1975) and from a viewpoint where the factors that influenced this situation gained limited attention. Rather, a number of other questions need to be asked related to factors such as: the time constraints imposed on the driver, the type and level of education provided, the existence and formulation of legal requirements, rules and procedures, the perceived meaningfulness of such procedures and their degree of correspondence with the actual work performed, the existence and effectiveness of inspections and enforcement, the scheduling of working hours, the type of behaviour encouraged by managers and other staff, etc. The more valuable lessons to be learned can in many cases therefore be found at levels higher up in the socio-technical hierarchy, where explanations of what factors that constrained the actions taken by the individual operators can be identified.

This means that factors at the microlevel often merely are symptoms of deeper trouble in the system (cf. Dekker, 2006; Rasmussen, 1990), i.e. they are manifestations of problems at higher levels. As pointed out

by Cook et al. (p. 25), substantial research points at the conclusion that accidents stem (directly and indirectly) from the manner in which constraints, resources, demands and incentives are produced by regulatory, administrative and organisational factors, rather than by the “errors” of individual humans in isolation. Therefore, factors at the microlevel only constitute a limited explanation to an event that involved multiple factors that interacted to result in an accident. In order to gain deeper understanding of the factors that contributed to the accident, for example understanding of why a specific operator acted the way he or she did in a particular situation, the situation must be understood from that operator’s perspective (Dekker, 2005). As pointed out by Hollnagel (2002: p. 4), “It is only by knowing what people did and why they did it that effective solutions can be devised”. It is therefore crucial that a rich description both of the factors contributing to the accident and its context is provided in order to gain a deep understanding of the event. This kind of descriptions need to focus on why the things that were done by people involved in the situation made sense at the time, given the resources and information available to them; otherwise the outcome of investigations only lead to what Birkland (2009: p. 148) refers to as superstitious learning, i.e. “learning without some sort of attempt to analyse the underlying problem”. This means that changes that are made to the system end up being restricted to “deviance corrections”, or adjustments of the existing strategy for reaching a fixed goal, corresponding to the lower orders of learning in the taxonomy proposed by Freitag and Hale (1997). As a result, higher orders of learning (referred to as double loop learning in the vocabulary of Argyris and Schön, 1996) are not achieved, which corresponds to measures that not only aim at changing the strategies for meeting a fixed goal, but also involves questioning the appropriateness of the goal itself.

In order to avoid that lessons learned from an accident investigation are restricted to deviance corrections at the microlevel, other competences than general technical and/or operational skills are necessary. Provision of a diverse number of competences is essential for enabling different types of lessons to be learned from an accident, as this kind of diversity in viewpoints can contribute with different descriptions of the same event. This is discussed by Cilliers (2005: p. 258) with regards to the description of complex systems:

“Since different descriptions of a complex system decompose the system in different ways, the knowledge gained by any description is always relative to the perspective from which the description was made. This does not imply that any description is as good as any other. It is merely the result of the fact that only a limited number of characteristics of the system can be taken into account by any specific description.”

Lundberg et al. (2009; 2010) point out that a complement to the sector-specific knowledge in the form of specialist competences is critical for drawing deeper and more varying types of lessons from an accident. In addition to a general understanding of how work is carried out in the relevant sector, the investigation of accidents therefore calls for substantial specialist knowledge of phenomena that are studied in numerous different fields (Rollenhagen, 2011; ESReDA, 2009), such as for example psychology, organisational theory, human factors, ergonomics, law, political science, etc. However, interviews with representatives from the three investigation boards showed that these types of specialist competences are rare. For example, despite the relatively large emphasis on factors at the microlevel (such as actor activities), it can be noted that it is not a standard procedure to engage investigators with specialist competence on for example human factors or psychology in any of the investigation boards, and in investigation board C such competence is not available at all. Furthermore, none of the investigation boards have specialist competences on factors that relate to the macrolevel.

One potential way for obtaining both an increased number of specialists and a larger diversity of viewpoints, despite limited resources, is to merge separate investigation boards from different sectors into larger multi-modal investigation boards. To some extent this has been done in all three countries, albeit with some difference in the number of sectors that have been merged (see Section 1). Several advantages with multi-modal investigation boards have been pointed out by for example Stoop (2004), such as shared

resources in administration, facilities and training. However, interviews with representatives from the three investigation boards in this study showed that the achievement of these potential synergies varied considerably between the countries. In investigation board C cross-sector synergies were practically nonexistent. None of the potential advantages associated with a multi-modal investigation board could be identified, apart from sharing the same facilities. As mentioned above, this investigation board consequently lacked a common pool of specialist competences, which could be found in the other two investigation boards, indicating a more restricted ability for gaining deeper knowledge of the different types of aspects leading to an accident. In addition, it should be noted that sharing the same facilities do not per se contribute to improvements of the accident investigation reports. According to the interviewees the limited cross-sector interaction within investigation board C was stemming from a perceived difference in cultures and traditions between the different sectors. In addition, each sector was considered “too specialised” for being able to benefit from one another, which consequently restricted the use of the potential advantages that to a large extent was the reason for merging the separate investigation boards in the first place. This means that, although a potential for cross-sector synergies can be identified in multi-modal investigation boards, they do not emerge automatically. Rather, the results from this study suggest that the investigators’ perception of the degree of similarities regarding how and why accidents happen across different sectors is influential for the ability to benefit from these synergies. It can therefore be concluded that merely co-locating multiple smaller but autonomous investigation boards responsible for different sectors in the same facility does not result in the possible advantages associated with a multi-modal investigation board.

In contrast, investigation boards A and B were characterised by significant cooperation across sectors. Cross-sector synergies were particularly exploited in investigation board B, which was manifested by the use of the same investigation method across all sectors, establishment of a common pool of specialists, provision of the same training in general investigation skills to all investigators, and the ability for investigators to assist colleagues working with other transport modes in large investigations, e.g. regarding interviews and more general undertakings. These characteristics facilitate involvement of people with different perspectives of the factors leading to an accident, which is essential for enabling more comprehensive analyses (Levesson, 2004; Svensson et al., 1999). This shows that investigation board A and B possessed a greater potential for undertaking more exhaustive investigations, and from the content analysis it could also be concluded that these investigation boards were capable of identifying a larger number of factors that contributed to the investigated accidents.

These results consequently show that if the potential synergies are fully exploited, merging investigation boards from different sectors into a multi-modal structure provides a promising step forward for the outcome of accident investigations. In addition to a number of practical benefits, such as shared facilities and administration, it can be concluded that the establishment of larger multi-modal investigation boards can favour the potential for learning from accidents. However, in order to achieve positive effects it is crucial that efficient cross-sector collaboration and exchange of knowledge and experience is facilitated. In particular, the possibility to provide a more diversified range of competences that is offered by the establishment of a multi-modal structure needs to be developed. Based on the findings in this paper, it is suggested that the provision of general technical and operational knowledge should be supplemented with specialist competences that are shared between the different sectors of the investigation board in order to provide different perspectives of the investigated accidents. This generates an increased potential to carry out investigations that offer deeper insights of the factors leading to an accident, which contribute with an improved ability for effective learning.

## 5. CONCLUSION

From the content analysis presented in this paper it can be concluded that the attributed causes in accident investigation reports from the three national accident investigation boards have a considerable emphasis on physical processes, actor activities and equipment, referred to as factors at the microlevel. Much less attention is paid to organisational factors (the mesolevel) and factors related to regulatory bodies, associations and governments (the macrolevel) in the investigation reports. The relative distribution of

attributed causes on the three hierarchical levels does not differ to any significant extent between the three countries. In absolute terms, however, major differences can be found. From interviews with representatives of the investigation boards it can be concluded that the focus of investigation reports typically reflects the competence and experiences of the investigators, i.e. that investigators are inclined to focus on areas of their own expertise. Since failures at the microlevel in many cases merely are symptoms of trouble at higher levels of the system, it is therefore suggested that competences among investigators that supplement entirely technical and/or operational backgrounds are necessary. This would provide greater diversity in perspectives, and is consequently a prerequisite for a more varying type of lessons to be learned. One potential way for increasing the number of specialist competences and broadening the variety of perspectives, despite limited resources, is the creation of multimodal investigation boards. This approach has to some extent been adopted in all of the studied countries, but the results in this paper revealed considerable differences in the ability to benefit from these potential synergies between the three investigation boards. It can be concluded that when these potential synergies are efficiently exploited, a multi-modal investigation board offers a potential to carry out exhaustive investigations that can provide deep insights of the factors leading to failures, and consequently contribute with an increased ability to learn from accidents.

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