Journal of Hazardous Materials 191 (2011) 158–162

Contents lists available at ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

Underestimation of language issues in frequently used accident investigation methods
A new taxonomy problem found in Dutch accident data

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ARTICLE INFO

Article history:
Received 10 January 2011
Received in revised form 12 April 2011
Accepted 14 April 2011
Available online 20 April 2011

Keywords:
Taxonomy
Accident investigation, Language issues
Diversity
Industrial safety
SEVESO

ABSTRACT

A wide variety of methods exist in the field of accident investigation. The challenge to find the cause for each and every accident has perpetuated a complicated and fundamental debate. In spite of the different paradigms, the many branch specific investigation methods, decades of accumulated and documented accident investigation experience, the diversity in taxonomy of causal factors, and an increasing depth of general systematic analysis tools, there are still causal factors missing out. A recent study identifies language issues as an underestimated danger. Dutch Labour Inspectorate records identify procedures and communication as an important causal factor area for major accidents. Accident investigation method taxonomies that are frequently used in The Netherlands, were investigated on the content related to language issues. Language issues are found to be either present less than proportional with observed accident rates or not present at all in frequently applied accident investigation classification systems. Hence a new taxonomy problem was found in Dutch accident data. Language issues need more attention in accident investigation methods.

1. Introduction

Australian aboriginals once used to find their way following in their ancestors footsteps with "song lines" [1]. They used the songlines to keep from accidental deviations from the right path so that they would walk astray. In modern safety management, a similar problem exists: if language problems exist, safety could suffer. This paper addresses the importance of language issues in accident investigations and how well they are addressed in accident investigation methods with a classification system frequently used in the Netherlands.

An important task of language is to allocate names and meaning to things in the perceivable environment and share this in a social context [2]. All human societies use spoken language and pass their knowledge on from generation to generation. Communication is most successful when the vocabulary in the language is shared between all inhabitants. On the other hand, language is also used to differentiate a group from other groups of people: there are different languages and dialects that distinguish between ethnographic groups and subgroups. It is these differences that may cause confusion about the meaning of some of the words. In ordinary life, this may not be a problem but when safety is at stake, errors are unwanted and need to be addressed. Lindhout [3] defines "Language issues" as: *problems related to communication either verbal, with signs and gestures or their written or stored equivalents*. Lindhout and Ale [4] present language issues against a background of a wide variety of underlying causes and promoting conditions. The term "Language issues" elaborates and at the same time extends beyond "poor communication". The issues comprise poor command of the language used on the shop floor, poor reading and writing skills, analphabetism, illiteracy, poor translation, unfamiliarity with gestures, pictograms or signs, poor readability and medical problems such as dyslexia dyscalculia. Causes are poor education and training and poor written or verbal communication. Conditions leading to language issues induced human error are personal development, the presence of foreign languages and a range of other disturbing factors like a multi lingual environment, cultural diversity and noise levels.

2. Scale of language issues in accident investigations

A Dutch major accidents trend analysis report of COT/DHV(2004) states that the classification in currently used methods obscures part of the language issues [5]. Finally, the Labour Inspectorate accident report over the year 2007 identifies "procedures and instructions" as the single biggest cause of major

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doi:10.1016/j.jhazmat.2011.04.056

accidents [6] where 5 years earlier that was "maintenance related activities" [7].

What can be expected in terms of language issues related causality? Lardner and Fleming find a 43% share of "procedures" related human errors in accidents in the process industry [8].

Cameron and Raman [9] report that research shows that 30% of the accidents in the process industry is caused by human error. Recently, language issues have been identified as an underestimated danger in Seveso II companies, with language issues estimated to affect up to 35% of all human error producing conditions [4]. This leads to a human error literature based estimate of the magnitude of language issues related causality in the process industry of about 10%.

This paper shows that frequently used accident investigation methods tend to underestimate the importance of language problems. Clearly, the figures show that this issue is too important to lay aside. This paper addresses this problem by designing a theoretical framework for taxonomy-based accident investigation methods and appraising the language related causal factors in them.

3. Theoretical framework for a scale of taxonomies of causal factors

3.1. Taxonomy and accident investigations

Accident investigations come in different types: descriptive, taxonomy based and combinations of those two. In both cases, finding causal factors and preventing future accidents are central aims.

Traditionally there is the causality concept that links cause and effect, sometimes referred to as "domino" theory [10].

Ignoring the phenomena of relativity and quantum mechanics we shall assume that cause precedes effect and that a relation, direct or via a chain of events, exists between the two [11].

3.2. Full text reports

Descriptive accident investigations are designated as one end of a scale of taxonomy of causal factors. The accident investigation methods and result in elaborate full text reports on an accident that describe the accidents and their context in the most detailed manner. The advantage is that the causal chain of events is (often) revealed and the context can be understood thoroughly. In this type of investigation no predesigned taxonomy of causal factors is used. Every conceivable type of cause may emerge from the investigation. Theoretically, there is an infinite number of causal taxonomy classification "sorting bins". However, it is unlikely that the same causes or types of causes are shared between any two reports, or in other words, it is unlikely that the same taxonomy classification bin is found twice. This jeopardizes efficient trend analysis and requires a lot of effort for trend analysts. Examples include the reports of the Three Mile Island incident [12], the Challenger Space Shuttle explosion [13] and the BP Texas City refinery explosion [14,15] resulted in examples of such in depth analysis reports. Each of these is considered to be ground breaking since they led to a paradigm change. They are also relevant for this paper because they mention language issues in -as yet obscure-relation to causality:

- 28 March, 1979, Three Mile Island core meltdown – Harrisburg, PA, USA. . .the wording of procedures must be clear and concise. . .
- 28 January, 1986, NASA Challenger SRB explosion – Florida, USA. . .a lot of these guys didn't know how to write good memo's. . .
- 23 March, 2005, BP refinery explosion – Texas City, USA. . .a miscommunication occurred regarding how feed and product would be routed. . .

So despite language not being a priority in these investigations it was still found to be a topic, which may be expected with an infinite number of causal taxonomy bins.

3.3. Limited number of causal factor bins

The other end of the scale of the taxonomy of causal factors is where all accident investigations lead to just one causal factor, e.g. human error. Especially in the earlier years of safety science this was a common finding, e.g. Heinrich [10]. This extreme end of the scale is not further considered as part of this paper. But close to that extreme end are accident investigation methods that are based on methods that make use of a few pre-programmed taxonomy bins for causal factors. Many accident investigation methods attempt to systematically identify groups of causal factors that have been contributing to the accident at hand and these groups have been classified into taxonomy groups. So, there is a defined and limited number of taxonomy bins. A wide variety of accident investigation methods make use of causal taxonomy groups for use in specific domains like aerospace [16,17] railways [18,19] road traffic [20] and chemical industry [21]. The advantage of these methods is that evidence from earlier accidents can be used to explain new accidents and speed up the implementation of solutions for accident prevention. Unfortunately, there are also inherent drawbacks to these methods. Firstly, there is the problem of taxonomy variety, complicating and constraining the translation of recorded accident experience to accident prevention activities [22]. Secondly, there is doubt about the proportionality of causal factors and the degree of ambiguity in the hands of different accident investigators [23]. Thirdly, accident investigators show differences in interpretation while using a classification. And fourthly, most accident investigation methods end up with an 'others' category where accident causes end up that do not fit the method's taxonomy. The taxonomy based methods also have some more fundamental problems. Wallace and Ross [24] explore the relation between taxonomy and safety and identify several fundamental flaws: taxonomy is to be agreed upon (is not finalized) and taxonomy is context specific (depends on the industry conditions). These flaws are important for accident investigation methods. Recent investigations in the Netherlands have prompted changes in their taxonomy classification systems. [21,25,26]. There is a further flaw related to unclear definition of the boundaries of the bins themselves. Wallace and Ross propose a probabilistic approach using sensitivity and specificity for evaluation of the suitability of class boundary definitions [24].

3.4. Explicit and implicit language issues

Literature search on language issues related causal factors, taking into account the above taxonomic difficulties, was done with two simple definitions. A causal factor is "explicit" when any of the words: language, communication, misunderstanding or literacy is present in the descriptive text. General accident investigation methods have in some cases no classification identifying any such explicit factors. This implies that language issues related causality is contained somewhere in the classification although not directly visible. Such causal factors are called "Implicit". An example of this would be ". . .failed to follow procedure. . ." in the descriptive text. This differs from ". . .procedure error. . ." and ". . .employee error. . ." and infers the presence of language issues as a part of causality.

Next, the 'density' of the classification bins must be sufficient to distinguish between language issue related causal factors like e.g. poor translation and poor readability. If a single taxonomy bin is explicitly allocated to a specific causal factor, other factors may still be present in an implicit way outside this bin. Hence, both explicit and implicit factors may be part of a classification [3].

3.5. Mixed approach

It is possible to use a hybrid form of accident investigation where different accident investigation methods are combined in an accident investigation project. Practice today shows examples of multiple investigation methods usage for a single accident investigation. This means that a mixture of taxonomy classification systems is applied to an accident. This method pushes the investigation further away from the 'single solution' side on the scale of the taxonomy of causal factors. This approach is somewhere in between the single method taxonomy based recording approach and the rigorous in depth full text reporting mentioned above because the number of taxonomy bins is increased but not infinite.

4. Method for language issues analysis

4.1. Selection of accident investigation methods for language issues analysis

There is a plethora of accident investigation and analysis methods [27]. No literature was found on comparisons of causal factor classification between them however. The range of accident investigation methods varies between methods for small-scale incidents; for example Barefoot [28] which is elementary and aimed at a single person's workplace safety, and methods for complex incidents NASA-FTA [16], a sophisticated and complex method for aerospace accidents investigation.

Alphen et al. [29] provide an inventory of frequently used accident investigation and analysis methods in the Netherlands. For this study that list was narrowed down to a few methods studied in this paper. Selection criteria were the following. (1) The methods are used in the field of major hazard control among Seveso II companies. (2) The methods that have an experience base of 10 years or more. (3) The method has to be based on a classification system.

Five methods were found with these selection criteria. The first one is SOAT which is used by the Dutch Labour Inspectorate for occupational safety incident investigation [30]. SOAT contains a relatively large number of causal factors covering all kinds of industrial activities. SOAT was enhanced by research conducted within the Labour Inspectorate by Jaspers [31]. This resulted in a new, more elaborate, general classification system of causal factors and a new investigation method in 2008 [26]. For further reference, we shall term this method 'Jaspers'. The third method is more commonly known: Fault Tree Analysis FTA according to a.o. the CPR-20 standard [32]. The fourth method is the Management Oversight and Risk Tree in MORT chart NRI-2 [25]. Finally the fifth method is TRIPOD which makes use of the Tripod General Failure Types (GFT) manual [21], and quick reference [33]. Each of these five methods cover the full range of accidents and therefore do not exclude any part of the causality domain on forehand. The selection also shows a spread over different types of methods. The SOAT and FTA method use pre-determined causal factors, MORT presents guidance for the identification of Less Than Adequate activities contributing to an incident, Jaspers presents a comprehensive historical synthesis of causal factors from accidents, and finally Tripod uses human error data to assess incident causality allocated to a limited number of risk factors.

4.2. Appraisal of language related causal factors in methods

Some of the selected accident investigation methods and their taxonomies for causes mention language issues as causal factors in an *explicit* way. These causal factors form one or more taxonomy bins: explicit language related causes. Some methods do not mention any language issue at all. Therefore it is necessary to investigate whether language problems are embedded in other causal factors, so they are present in an *implicit* way. These factors form other taxonomy bins: implicit language related causes. Furthermore the differences in relative attention to language issues and the underestimation of the dangers associated lead to the assumption that there can also be a mix of both explicit and implicit causal factors in a classification system. This study investigates both types.

An explicit causal factor is identified by key words that include: language; translate; interpret; understand; instruct; read; verbal; written; communicate; all pointing out a language issue. Finding implicit causal factors is done by means of appraisal questions. The first one is: "*would someone in this situation require verbal or written instruction to avoid making a mistake?*". The second one is: "*would many other dangers than language issues related danger be more likely in this case?*". The second question was used to refine the selection of causal factors. Factors with a highly general nature; comprising also many other causes besides language issues; were removed from the selection.

Once implicit causal factors were found the relative 'strength' or presence of language issues in them was assessed. This was done by associating the language issues in implicit causal factors with 22 specific language issues related dangers or LRD's found in literature [4]. Each implicit causal factor was compared with each of the 22 dangers using an appraisal question: "*can the causal factor lead to the language issue related danger (LRD) at hand?*". If the question must be answered with "yes" a score of 1 point was allocated. In all other cases no points are allocated. By adding all points given to a specific selected causal factor an indication value between 0 and maximum 22 for the strength of the implicit relation is obtained. A strong match is found when more than half of the LRD's relate to the implicit language related causal factor at hand and no correction is applied [3].

This appraisal method was used on the five selected accident investigation methods Tripod, FTA, MORT, SOAT and Jaspers.

5. Results for 5 frequently used methods

5.1. TRIPOD

The Tripod family of methods has recently been updated, leading to the main 11 identifiers names changed from General Failure Types (GFT) to Basic Risk Factors (BRF). This study uses the GFT version classification. This version has both a "manual" and a "quick reference" classification.

5.1.1. Quick reference

The quick reference version shows 11 GFT's with 81 causal factors in total. Language issues are explicitly addressed in 3 of the 81 factors (3.7%). Implicit factors were not investigated in the quick reference version.

5.2. Manual

The manual version contains a more elaborate list of 132 causal factors for the 11 GFT's. In total 3 explicit factors are found (2.3%). Besides the 3 explicit language issues related factors in 2 GFT's some 22 other causal factors, spread over all GFT's, showed implicit language issues. They match with, on average, 10 out of the 22, so slightly less than half the LRD's. Since the Tripod method is the only one of the five methods investigated having a bin "8-CO Communication-all language issues" a reduction factor of 10/22 is applied here on the percentage of implicit causal factors as explained earlier. This compensates for the fact that an implicit causal factor could be allocated to either of two bins. Hence language issues of varying magnitude are present in 25 out of 132 causal factors spread over all 11 GFT's. This means that implicit language issues together take a 22/132*10/22 part of the causal factors list (7.5%) in the Tripod manual version.

The addition of explicit and implicit factors in the Tripod manual version reaches 9.8%, considerably higher than the method manual explicitly states with 2.3%.

5.3. FTA

CPR-20 presents 134 causal factors in total. No language issues are explicitly mentioned (0%). This means that investigation and recording with this classification system does not flag up language issues as a causal factor. There are 16 selected causal factors showing implicit language issues. On average the 16 factors strongly match with 14 out of the 22 LRD's. No reduction factor is applied here since there is no language issues bin. This means that implicit language issues take a 16/134 part of the causal factors list (11.9%) in the CPR-20 fault tree.

5.4. MORT

The MORT Chart 2002 version presents 197 causal factors. None of them explicitly mentions language issues. (0%) Selection delivers 21 factors with implicit language issues content. These strongly match with on average 13 out of 22 LRD's. No reduction factor is applied. This shows that 21/197 part of the MORT classification are implicit language issues related causal factors (10.6%).

5.5. SOAT

The SOAT chart Direct Cause and Root Cause groups are used for the selection. Overlap between the direct- and root-groups was ignored. In total 175 causal factors were found. Only 1 explicitly mentions a language issue (0.6%). Selection results in some 19 implicit factors with a strong match with, on average, 15 out of 22 LRD's. No reduction factor is applied here since the one explicit bin found only covers a very specific requirement on translation of standards. Other language issues would not likely be allocated to this bin. This shows 19/175 part of the SOAT classification to be implicitly language issues related causal factors (10.8%). In total 11.4% is language issues related.

5.6. JASPERS

Jaspers [31] presents a 384 causal factors list with 4 explicit language issue related factors (1%). Some 26 other factors show implicit language issues (6.8%). In total this leads to 30/384 or 7.8% language issues related causal factors in the Jaspers list. No match with the 22 LRD's was analyzed since this causal factor array is new and no accident recording data is available on this basis.

Lindhout [3] presents a detailed tabulation per accident investigation method of explicit and implicit language issue related causal factors and their match with LRD's. Fig. 1 shows the results of the factor counts and LRD matching

6. Discussion

This paper brings to light that there is a discrepancy between the occurrence of language related accidents on the one hand and the attention language problems receive in accident investigation methods on the other hand. From the literature Lardner & Fleming 1999 [8], and Cameron & Raman [9] and Lindhout & Ale 2009 [4] it can be deduced that about 10% of the accidents in process industry is directly related to language problems. This work shows that language issues are poorly represented explicitly as causal factor in frequently used accident investigation methods in the Netherlands: Tripod 2.3%, Jaspers 1%, SOAT 0.6% and for Mort and FTA they are not mentioned at all. This is a clear sign that language issues are underestimated: the relative size of the taxonomy bins for explicit causes related to language problems is about 4 times smaller than proportional based on the literature and the analysis presented here.

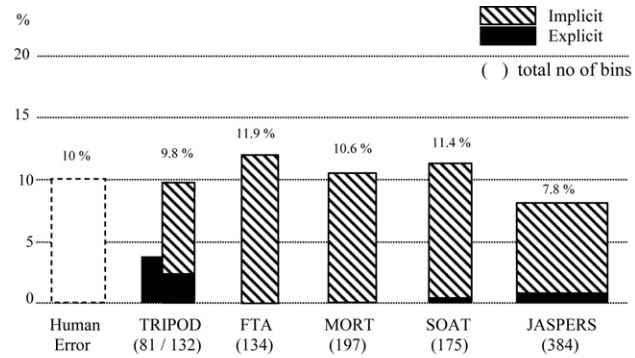

Fig. 1. Allocated percentages of explicit and implicit language issues related causal factors for 5 accident investigation methods, compared to a human error literature based estimate by Lindhout & Ale [4].

Although there are not many causal factors explicitly related to language issues, this paper also shows that many more causal factors have implicit language issues incorporated within them. When adding that category to the explicit one the balance changes: Tripod 9.8%, FTA 11.9%, Mort 10.6%, Soat 10.8%, and Jaspers 7.8%. This addition appears to close the gap between the accident statistics and the attention for language issues in accident investigation techniques. Looking at the taxonomic difficulties and flaws identified above it is clear that percentage differences between methods may be expected.

The relative size of both explicit and implicit taxonomy bins for causes in which language plays a role added together is about the same as the estimated contribution to accidents from human error literature and process industry accident rates. However, the implicit nature of most of those causal factors gives rise to uncertainty and misunderstandings about language issues. This vagueness about such an important causal factor group is unwanted.

Following Wallace and Ross' proposal that a probabilistic approach should be used for evaluation of the suitability of class boundary definitions [24] we propose that it would be better when about 10% of the causal factors in accident investigation techniques would address language issues explicitly. It is plausible that this would also be needed in many other industrialized countries accepting workers from abroad and having a part of the population with illiteracy problems. For this reason this taxonomy problem discovered in Dutch accident data is expected to have international significance.

Fortunately there are forces that change accident investigation techniques over time. The strength of a method in prevention of future accidents becomes a basis for the redesign of existing methods [34]. Methods are evaluated against newly proposed criteria [35]. Methods are also being expanded towards more general usage. These changes offer an opportunity to incorporate language problems explicitly. In addition, new investigation methods are being proposed to overcome the shortcomings in existing methods or due to new emerging technologies. Simultaneous application of different investigation methods is proposed for a single accident [36]. They also offer opportunities for incorporating language issues as an important contributor of language related causal factors.

7. Conclusion

This work brings to light that explicitly stated causal factors on language issues in accident investigation methods analyzed in this work (Tripod, FTA, Mort, Soat, Jaspers) have a share of between 0% and 3.7% which is much lower than an estimated 10% of accidents in the process industry where language issues are a causal factor [4]. Though the evidence in this work is limited to five methods and an estimation in the process industry, we conclude that the problem is a systematical one.

Since language issues have a wide variety of causes and require an equally wide variety of countermeasures a single taxonomy bin – or none at all – will not do. To ensure properly differentiated learning from accidents and specific feed-back to prevention activities, the allocation of taxonomy bins ought to provide sufficiently density. The current mismatch in proportionality is troublesome because it makes it easy to overlook language issues, especially since some methods have no explicit causal factors for language issues at all. It is magnitude of some 10% makes it an important group of factors. Use of the taxonomy principles and a scale, starting from a single sorting bin, first passing a 'lean' range – few bins – then a 'rich' – many bins – range and ending at an infinite number of bins, has been useful since it makes it easier to understand the problem. For an investigation at the 'lean' side of the scale overlooking language issues is likely, especially for investigation methods without explicit causal factors related to language issues. Using more than one taxonomy based investigation methods in combination, shifting towards the 'rich' range of the taxonomy scale, the likelihood of identifying language issues as a cause get better. If performing a descriptive accident investigation, chances of finding language related issues are, theoretically, the best because there is an infinite number of taxonomy bins. But, also there is no reminder that language issues might be a problem so they could be completely overlooked.

Fortunately, there are many forces that improve current accident investigation methods and drive the design of new ones. In light of this work, we conclude that those developments should include higher proportion of causal factors explicitly related to language issues.

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