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Reliability of accident case histories concerning hazardous chemicals

An analysis of uncertainty and quality aspects

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Abstract

A recent analysis of accident case histories achieved from readily available accident lists, has exposed the fact that an accident may be described more than once in the literature. Important discrepancies were found between the various main (accepted) sources in the field of risk analysis and loss prevention. An analysis of the differences found, and an assessment of the quality of accident case histories is attempted. Initially the analysis is limited to the number of fatalities, because this information is easy to measure, often available and lends itself to easy statistical treatment. The number of fatalities can thus be used as an indicator for the variability of the information found in accident case history reporting. The analysis is based on 595 transportation accidents involving hazardous chemicals from road, rail and pipeline transportation modes. Thirty-nine of these accidents were found to have three characteristics in common: (1) they happened before 1980, (2) they resulted in fatalities, and (3) they were described by more than one source. These 39 accidents are used in the analysis of the reliability of the number of fatalities reported in case histories. Sixteen accidents (or 41%) show discrepancies (in terms of fatalities) between the sources. Extrapolating the results of the "fatality" analysis to the other parameters, and supported by an analysis of selected cases, the general quality of information from accident case histories is evaluated. The result is a useful tool for assessing the quality of the various types of information. Using the terms "low", "medium" and "high" to describe the quality, a table can be compiled. This tool shows that the information on date and place of the accident is of high quality, the event description and the number of casualties are of medium quality, and the information about chemical name and amount is of low quality.

1. Introduction

Accident case histories concerning hazardous materials are an important source of (background) data for risk assessment. Obviously case histories contain extremely important information about what actually went wrong, rather than "what may go wrong", which is the normal result of a risk assessment.

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Accident reports found in the literature or in closed databases will, however, also reflect non-technical aspects such as the social and institutional context in which the report is drafted. To some extent the accident report may thus reflect the culture of the organization and the environment in which it is situated (e.g. reflecting whether the organization is penalized as a result of the accident).

A typical accident case history appearing in an accident list will contain a number of data related to the accident, ranging from the date and place to the chemical(s) involved. Often, however, important information may be lacking or incomplete.

A recent analysis of accident case histories achieved from readily available accident lists [1], exposed the fact that an accident may be described in more than one list. Important discrepancies were found among various sources. The present paper is an attempt to analyse the differences found, and assess the quality of both the accident case histories and of the underlying accident reporting systems.

2. Sources for accident case histories

Large accident databases already exist (e.g. FACTS—a databank for incidents with hazardous materials, managed by TNO, The Netherlands) and new databases are being constructed (see [2] for a survey). The Joint Research Centre, Ispra, for example is managing a database (Major Accident Reporting System, MARS [3]) containing a description of the accidents notified by the Competent Authorities from the member states to the Commission of the European Communities according to article 11 of the Major Accident Hazards Directive.

Current accident databases are all "extract" databases, i.e. they do not report the full text of the primary source(s). The information included in the databases will therefore be an aggregation, thus adding an additional filter on the information.

In addition to these (closed) databases, accidents are nearly always reported in the open literature, which is one of the major information sources for accident databases.

For important accidents the literature will usually publish a detailed account of the event, trying to illuminate interesting details, which may vary according to profession. Different descriptions of the same accident may hence be found in for instance journals for process engineers and journals for insurance brokers.

3. Contents of accident case histories

Large differences in information detail can be observed in the open sources, varying from lists containing *date, place* and one or two other parameter(s) of

interest to the author of that source, to detailed descriptions of single accidents. All accident case histories, however, typically contain the following information (minimum description):

- Date and place of the accident
- Description of the event
- Description of the consequences
- Number of fatalities and injured
- Type of chemicals (and quantities) involved

Some of the information, like the description of the event, consequences and type of chemicals may naturally vary in terms of completeness and level of detail.

In the following section the discrepancies in the number of fatalities will be discussed, whereas in Section 5 the more qualitative differences will be discussed.

4. Discrepancies in reported number of fatalities

This analysis is based on 597 transportation accidents with hazardous chemicals from road, rail and pipeline transportation modes. In Table 1 the distribution of these accidents, according to the number of sources describing them, is listed. The most recent accidents (after 1980) are often described in only one source, therefore the differences in the information offered by the various sources is best analysed if the time period considered is before 1980. For this period several central sources are available (Lees [4], Handbuch Störfalle [5], COVO [6] and HMSO [7]) making the discrepancies and differences clearly visible.

The analysis is initially limited to the number of fatalities, because this in-

TABLE 1

The sample of road, rail and pipeline accident descriptions, analysed for number of sources found as descriptors. The sample is divided in accidents before 1980 and in the period 1980–1988

Number of sources (N)	Number of accidents described by N sources	Before 1980	1980–1988
1	515	225	290
2	45	37	8
3	18	18	0
4	10	10	0
5	6	6	0
6	1	1	0
Total	595	297	298

formation is easier to measure, it is often available, and it lends itself to easy statistical treatment. It can thus be used as *an indicator for the variability of the information found in accident case reporting* (descriptions of injury as "serious", "severe", "slight" etc. vary with the author).

In Table 2 the number of accidents with one or more fatalities is shown according to the number of sources in which a description can be found. In the situation where only one source describe the accident, naturally no discrepancies are found between the information about the number of fatalities. As soon as more than one source describes the accidents, however, divergence is found in some of the cases. The number of cases with discrepancies is shown in the third row of Table 2 and the percentage of these cases is calculated. A discrepancy is defined here as (minimum) one source not being in agreement with the others. It is therefore to be expected that the percentage of cases where discrepancies can be found will increase with the number of sources, as indeed is seen.

In Table 3 the mean number of fatalities from the same 96 cases are shown according to whether all sources are in agreement or not. As seen in Table 3, the mean number of fatalities related to the cases with discrepancies are consistently higher than for those cases where the sources agree.

The total average of the fatalities reported by 2, 3, 4 and 5 sources gives an average with more than double the number of fatalities for cases with reported discrepancies than for cases where the sources agree. Discrepancies are thus, surprisingly, found for larger accidents, where a better reporting would have been expected.

One way of representing the uncertainties found in the number of fatalities

TABLE 2

The sample of road, rail and pipeline accident descriptions with one or more fatalities from the period before 1980. The sample is analysed for number of sources found as descriptors and how often the sources disagree

Number of sources (N)	Number of cases described by N sources	Number of cases with discrepancy	Percentage discrepancy
1	57	-	0
2	17	3	18
3	8	3	38
4	8	5	63
5	5	4	80
6	1	1	100
Total	96	16	-
Total with $N>1$	39	16	41%

TABLE 3

The sample of road, rail and pipeline accident descriptions with one or more fatalities from the period before 1980. The sample is analysed for how the number of fatalities varies with the number of sources describing the accident

Number of sources	Cases with agreement between all sources		Cases with diagreement between sources	
	Number	Mean number of fatalities	Number	Mean number of fatalities
1	57	5.8	-	-
2	14	2.5	3	6
3	5	5.8	3	13.8
4	3	2	5	4.8
5	1	7	4	9.9
6	0	-	1	183

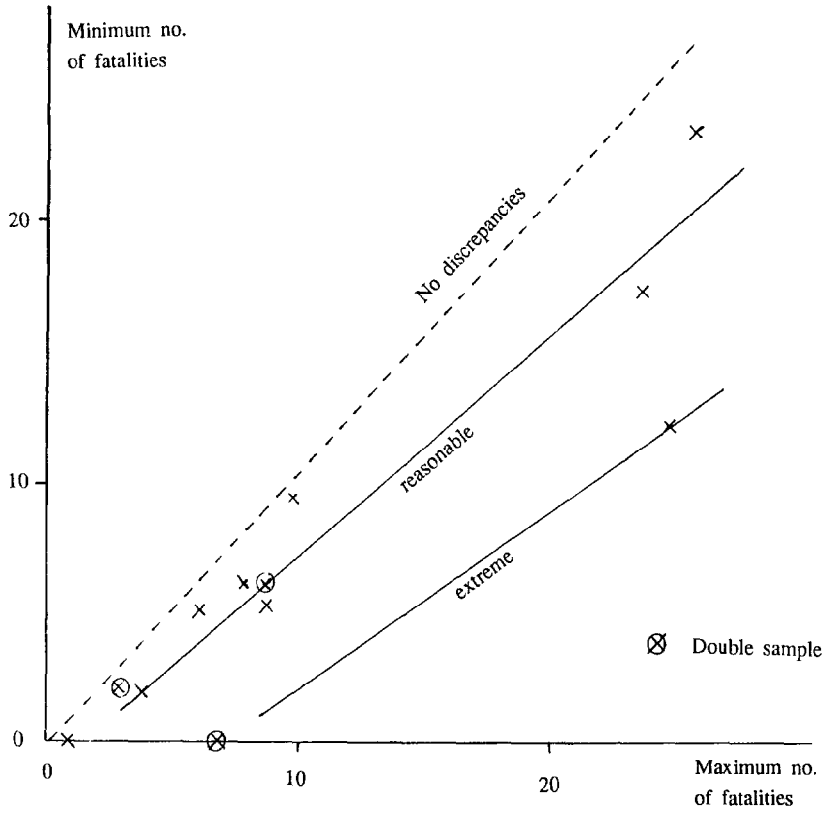

Fig. 1. Double plot of maximum and minimum reported number of fatalities in the 15 cases with discrepancy in the reported number of fatalities. An extreme and a "reasonable" confidence limit is shown.

is to make a diagram of the maximum and minimum reported number for the 16 cases available (2–5 sources). In this diagram the maximum number of fatalities reported is plotted against the minimum number of fatalities reported, thus giving the actual confidence limits found in the sample. This is shown in Fig. 1 (excluding the San Carlos accident (reporting of 150–216 fatalities) due to the scaling). This diagram gives an indication of the uncertainty of the number of fatalities as a function of the number of fatalities.

5. Qualitative and quantitative discrepancies in selected accidents

In the following a number of selected accidents are compared in an attempt to illustrate important uncertainties found in accident cases.

The first example (Table 4) concerns two cases found (only) in one source [6]. The descriptions show such an agreement that it is likely to be the same accident reported twice. The possibility of the same accident being present more than once in the same list, can cause problems for instance when performing statistical analysis of the datasample. Special attention should therefore be given to avoid this pitfall.

The second example regards the completeness of the sources. To compile a complete list, meaning a list containing all accidents which are of interest in a specific field, is an impossible task (as discussed by Marshall [8]). It was, however, expected that above a certain severity an accident list would be complete. Naturally it was expected that for less severe accidents, further accidents would be identified when using more than one source. Badoux [9] proposes a graphical illustration of the differences between full and observed distribution for the size of an accident. Figure 2 is an extended version of this illustration, which shows the expected increase in completeness resulting from the uses of multiple sources.

TABLE 4

Two accident descriptions from COVO [6], which are expected to be the same accident

Date	March 30, 1971	1972
Place	Rio de Janeiro, Brazil	Brazil
Substance	LPG	Butane
Event	UVCE	UVCE
Fatalities	38	37
Injuries	53	53
Text description	Frozen open water draw off valve on bottom of storage sphere (continues)	Frozen open water draw off valve on bottom of storage sphere

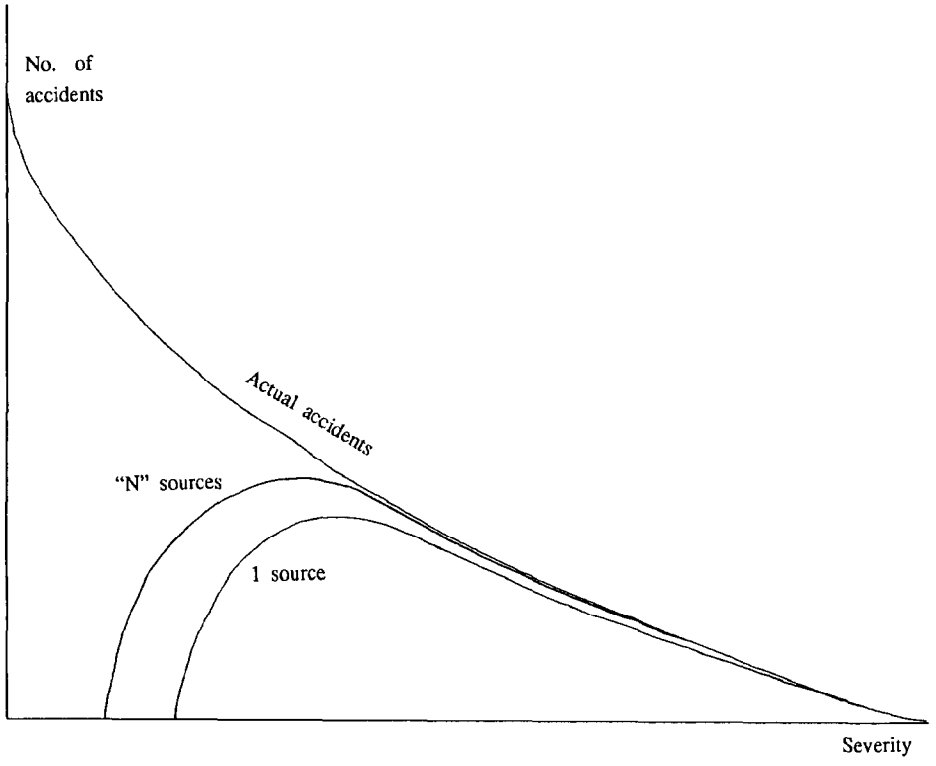

Fig. 2. Illustration of the expected increase in the number of observed accidents for the size of accident and number of sources [9], improved by the authors.

TABLE 5

Three accidents which would be expected to be found in at least one additional source. The "Deer Lake" accident was present in both [10] and [5], and no discrepancies between the two were observed

Type of information	Source		
	Handbuch Störfälle [5]	Martinsen and Calvin [10], Handbuch Störfälle [5]	Lees [4]
Date	January 22, 1959	June 2, 1959	1966
Place	Monroe, LA, USA	Deer Lake, PA, USA	Larose, LA, USA
Substance	Butadien a.o.	LPG	NGL
Event	Explosion	Explosion (BLEVE)	Fire
Fatalities	8	11	7
Injuries	75	10	-

Cases were found, however, regarding 7–10 fatalities (which a priori was thought to be rather severe), which were not reported in important sources. This is illustrated in Table 5, where three important accidents (in terms of human lifes) were found in one (or two) source(s), but not in any of the others. Even though no firm conclusions can be drawn on basis of three examples, they do show that even accidents with multiple fatalities may be missing in extensive lists. As shown in Fig. 2 the percentage of reported accidents is assumed to increase (to a level near 100%) with increasing consequences. The present analysis show that this threshold is reached with fewer fatalities by using multiple sources. However, even for accidents taking place in Western Europe and North America there is reason to believe that the threshold is not reached until 20–30 fatalities. This result is in agreement with [8].

The discrepancies between sources are finally discussed. In the textbox an analysis of five accidents from the USA in the period 1969–1978 which were reported in at least three sources and of the accident at Los Alfaques, Spain at July 11th 1978 is shown. This analysis illustrates that accident reports are not homogeneous, and that the amount of chemicals and the number of injuries (where reported) are more uncertain than the reported fatalities, and that the description can also vary considerable.

Six selected accidents

- Laurel, Mississippi, USA, January 25th, 1969.
  Lees [4]: 2 fatalities, 976 injuries
  Handbuch Störfälle [5]: 2 fatalities, 976 injuries
  Martinsen and Cavin [10]: 3 fatalities, 32 injuries
  Concordance is observed on the *substance* (two sources report LPG, and one propane and butane). The *main event* varies from derailment to BLEVE (Boiling Liquid Expanding Vapour Explosion), which must be interpretated as a difference in the level of interest. Though discrepancy is not observed, the case illustrates the difficulty in describing the main event homogeneously.

- Crete, Nebraska, USA, February 18th, 1969.
  Lees [4]: 8 fatalities, 20 injuries
  Handbuch Störfälle [5]: 9 fatalities, 53 injuries
  COVO (Commission for the Safety of the Population at Large) [6]: 8 fatalities, 35 injuries
  HMSO [7]: 9 fatalities
  Martinsen and Cavin [10]: 6 fatalities, 53 injuries
  All sources agree upon the *substance* (ammonia), but the *amount* is reported as respectively 64 and 90 tonnes. The *main event* varies from toxic release to BLEVE, which not necessarily is a discrepancy. The BLEVE could on the other hand indicate the presence of a fire due to a leaking petrol tank, which would be an important information in the evaluation of the consequences. Several similar observations of differences in the reported amounts released were made in this study.

- Climax, Texas, USA, June 29th, 1974.
  Lees [4]: 0 fatalities
  Handbuch Störfälle [5]: 7 fatalities
  HMSO [7]: 0 fatalities
  The *main event* is an explosion (Ref. [5] reports derailment, release and explosion), and the *substance* is VCM/vinylchloride. Reference [5], however, reports two other substances as well (hexamethyldiamine and leadtetraethyl). The *amount* is respectively not reported and reported as 100, over 100 and 110 tonnes. It should be noted that Handbuch Störfälle [5], which seems to have the most extensive information on the other records, reports 7 fatalities and the others agree on 0 fatalities. This case clearly illustrates the problem of deciding which source(s) to be regarded as giving better information.

- Waverly, Tennessee, USA, February 24th, 1978.
  Lees [4]: 12 fatalities, 50 injuries
  Handbuch Störfälle [5]: 25 fatalities, 50 injuries
  Martinsen and Cavin [10]: 16 fatalities, 43 injuries
  The *substance* is LPG/propane and two sources report the *amount* to be 45 tonnes (the last one does not report this information). As can be seen, large discrepancies are observed on the number of fatalities, discrepancies which are difficult to explain. The *main event* is an explosion (both BLEVE and UVCE—Unconfined Vapour Cloud Explosion—with subsequent fire is reported).

- Youngstown, Florida, USA, February 26th, 1978.
  Lees [4]: 8 fatalities, 50 injuries
  Handbuch Störfälle [5]: 8 fatalities, 114 injuries
  COVO [6]: 8 fatalities, 138 injuries
  The *substance* is chlorine but only Ref. [5] reports the *amount* ($30\ m^3$). All three sources agree that a toxic release is the *main event*, but COVO [6] (as the only source) reports explosion and fire as previous events, which, as mentioned in the second case, are important events in the interpretation of an accident. Large variation in the number of injuries is observed, but at least consensus about 8 fatalities is seen.

- Los Alfaques near San Carlos de la Rapita, Spain, July 11th, 1978.
  Lees [4]: 211 fatalities
  Handbuch Störfälle [5]: 216 fatalities
  COVO [6]: 170 fatalities
  HMSO [7]: "more than 150" fatalities
  M.T. [11]: 216 fatalities
  Stern [12]: "more than 200" fatalities
  All sources agree about the *substance* (propylene). The *amount* is in Handbuch Störfälle [5] reported as 22 tonnes and HMSO (as the only other source that reports the amount) adds a question mark to this amount. The *main event* is respectively reported as fire, BLEVE and (merely) explosion. It should, however, be noticed that COVO [6] and Handbuch Störfälle [5] as the latest sources (Nov. 1981 and 1983) report a BLEVE. Several extensive analyses have been reported on this accident which is the most severe transportation accident in this century (see e.g. [8]). Finally it should be mentioned that one expert has claimed that people were actually frozen to death in the initial (cold) gas cloud [14], released when the pressure vessel ruptured. None of the six sources specify this event.

6. Discussion

The accident case histories on which this study was based were collected with the purpose of comparing the severity of accidents during (road, rail and pipeline) transportation of hazardous chemicals and on fixed chemical installations (see [1]), based on the number of fatalities. Special attention was given therefore to the reliability of this parameter which can thus be used as an indicator for the variability of the information found in accident case reporting.

Only short descriptions obtained from accident lists were used in this study. The authors recognize that parts of the uncertainty could be eliminated by using comprehensive sources (like e.g. the reports of National Transportation Safety Board). This, however, was not within the scope of this paper.

The datasample used consist of 595 accidents. Of these 595 accidents 39 are described by more than one source and happened before 1980. These 39 accidents are used in the analysis of the reliability of the number of fatalities reported in case histories. Sixteen accidents (or 41%) show discrepancies between the sources.

In the absence of further information it seems safe to assume that the reliability of the remaining 556 accidents, which are either described by only one source, or accidents where no fatalities are reported, are not better than the accidents used for the testsample. It may also be mentioned that the differences found in the description of the transportation accidents are indicative also for similar areas where accidents are reported.

By extrapolating the results of the "fatality" analysis to the other parameters, and supported by the analysis of a number of selected cases (and several similar), the general quality of information from accident cases can be assessed. The best quality information is actually the date, and even this information is sometimes doubtful. The quality of the information about the place of the accident varies and often only the country is known for sure.

The description of how the accident happened was found to be rather uncertain. Information on the main event varies with the interest of the source. Some sources frequently report "collision" and "derailment" and continue to report the event sequence, others use "release" or "toxic release" (and do rarely report a previous fire or explosion). Some examples are seen of minor discrepancies between the events reported.

The information about the chemical is often found to be unprecise. It is furthermore very rare to observe specifications of pressure and temperature of the substance. Information on the amounts released is rare (more often the amount involved in the accident (e.g. the number of tonnes present in the tank) is reported), and is seen to be uncertain (if reported).

In Table 6 the results of the present analysis are given in a compressed form, evaluating the types of information, by one of the three qualifiers: high, medium and low (quality).

TABLE 6

Ranking of the types of information found in the case stories, based on the present analysis

Type of information	Quality	Uncertainty observed
Date and place	high	Generally this information is present and accurate. Variations of days or years are sometimes observed.
Description of event	medium	Cases of discrepancy and of differences in reporting-level have been found, but generally the sources agree upon the main event.
Number of fatalities	medium	Of 39 case stories discrepancies were observed in 16 (41%), ranging from 0–7 to 22–25 fatalities.
Chemicals	low	The use of commercial names of chemicals is frequent. The physical conditions of the substances are rarely specified.
Quantity of chemical	low	Discrepancies of a factor of 2 to 3 and unprecised units. Is often missing.

7. Conclusion

The quality of the data of accidents case histories is important because it serves as input to risk assessment, where extrapolation from few data is the norm. It is therefore essential to have high quality data, which is not the same as data without uncertainty [13].

However, as shown here, most short descriptions of accidents can be assumed to be uncertain on most points. This uncertainty will naturally depend on the authority of the source, but even in some cases where the source must be considered authoritative, low quality information may still be found.

From this analysis it can be concluded that the (low) quality of the information cannot simply be dismissed as arising from unreliable sources. It should rather be considered as inherent to the reporting process and subsequent selection of the information thought to be important.

Uncertainty will always be inherent to any analysis based on accident case histories.

For statistical studies it is also important to consider that the reporting threshold differs widely depending on factors such as country, industry, time, social context etc. In some cases this can lead to the creation of "epidemics" of accidents, because the reporting procedure or threshold has been changed or because more recent sources are used. This uncertainty must be considered as additional to the uncertainty inherent in the accident case histories.

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