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A LOOK AT DATA SITUATION IN PROBABILISTIC RISK ANALYSIS AS APPLIED TO STRUCTURAL SYSTEMS

E. R. Vaidogas

1. Introduction

Industrial facilities containing structural systems (buildings, engineering structures and services) are physically immovable and so they are exposed to a wider range of risks than investments in movable property. The existence of the risks for a facility and so structural systems inside of it gives rise to a need to manage risks. The necessary mechanism to do it is provided by the risk management [1, 2]. In a broad sense, the risk management is defined as a methodology which aims to identify, quantify and reduce (eliminate) a large part of risks to which a facility and thus the business utilising it are exposed.

The technique of probabilistic risk analysis (PRA) or quantitative risk analysis has been developed for the quantitative assessment of the risks and, more generally, as a decision-making tool used to manage risks [3, 4]. This technique originated in nuclear power and chemical industries is more and more extensively used in other fields of engineering, including civil engineering and structural engineering [5, 6, 7].

The methodology of PRA overlaps in many respects with the risk management which concerns to a large extent problems of risk transfer and has been developed beyond the management of an insurance portfolio [1]. The insurance may play a major part in the indirect financing the risk reduction projects [1, 8]. The effectiveness of the projects, in turn, may be measured by means of PRA.

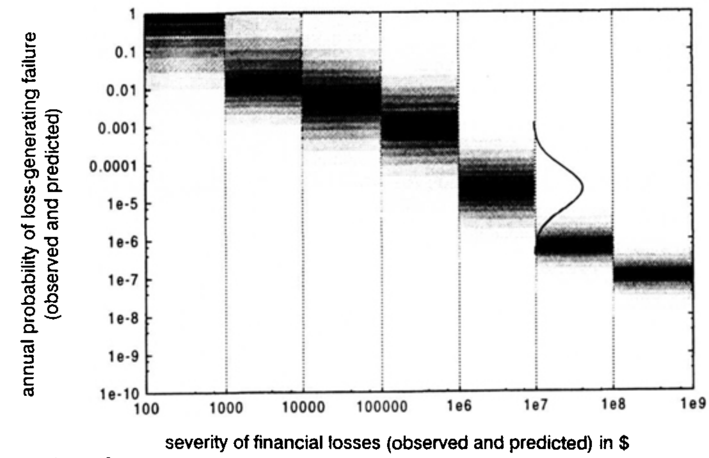
As the name implies, PRA uses probabilistic methods to quantitate risk. Consequently, a successful application of PRA is completely dependent on availability and quality of statistical data necessary to fit the probabilistic models. Moreover, the complexity of phenomena which PRA attempts to simulate may require to have at hand data of all relevant kinds first of all reliability data, unavailability data and accident data.

In the present paper an effort is made to take a look at the data situation in the field of PRA as viewed from the position of the structural engineering. Attention is centred on the accident data in view of the fact that error free structures fail usually under abnormal service conditions including those created during severe accidents. Although several collections of accident data are briefly reviewed in this paper, it is not intended as a detailed study of the gathered empirical information. The data situation is considered bearing in mind an integration of PRA with the probabilistic structural analysis. The consideration deals first with some aspects of the risk management which are directly related to the data problem. Then the availability, accessibility and suitability of accident data is discussed.

2. Risk management in structural context

If not identical with insurance, the risk management is primarily used for decision-making in the insurance area. This is reflected by the main branch point in the flowcharts of the risk management process shown in the published literature [1, 2, 9]. A competent person or body, having identified, quantified and, wherever possible, reduced the risks to which a facility is exposed, must decide whether to retain or to transfer them.

It would be an overstatement to say that all participants of the risk management process, first of all owners and insurers, will accept an application of the formal mathematical methods developed in PRA as the only way to assess risk. On the other hand, the definition of risk and methods of its quantitation used in PRA correspond in essence to the ones applied by



Note: e-6 = 10^{-6}

Fig1. Hypothetical relationship between categories of financial losses and frequency of their occurrence (see also [12])

property insurers (eg [1]). Therefore, one can expect that the attitude of the property insurers to PRA will be positive.

It is deemed that risks associated with small, repetitive losses are best suited to retention; conversely, risks generating catastrophic losses of low frequency are most appropriate for insurance [1, 2, 10]. The majority of risks fall somewhere between the two extremes. A deterministic relationship between magnitude of losses (consequences) and frequency of their suffering does not exist, of course, and the participants of the risk management process will always have to face the uncertainty in prediction the frequency of a particular category of losses. This circumstance is illustrated by Fig 1.

The commercial insurance can cover almost all risks of physical losses resulting from damages or destruction a facility may suffer, as long as the owner is ready to pay required premiums. Lists of loss generating events appearing even in the "standard" policies of property and building insurance are very extensive and the coverage of such policies can embrace in fact the whole range of risks falling between the above-mentioned extremes [10]. Some kinds of facilities may, of course, have limits of insurability which are set by amount of catastrophic losses due to major failures in these facilities. It should be noted at this point that the risk transfer to the commercial insurance is not the only solution to meet costs of losses if they occur, and other possibilities of the risk transfer are known in practice (eg see [9]).

The insurance against risks arising from repetitive events causing small losses, on the one hand, and rare events (failures) with high consequences, on the other, is usually faced with substantially different possibilities to quantitate both frequency of the adverse events and consequences of their occurrence. The possibilities are determined primarily by the availability and applicability of risk-related data gathered in the past experience.

The problem of insurance against a particular risk presents no difficulties if the insurer has good actuarial data about losses under consideration. Small vandalism losses, breakage of glass, or even small-loss and medium-loss fires[1] may be mentioned here as examples. In such cases, quantitation of risks and calculation of insurance premiums is, at least in principle, possible on the basis of representative samples recorded in reasonable periods of time. In contrast to this, it is impossible to estimate from statistical evidence probabilities of the serious failures which are unlikely to occur in the facility under consideration during the period of interest. The same is also true for the evaluation of the eventual amount of losses imposed by the rare failures.

In spite of the difficulties with quantitation of risks arising from rare failures, owner(s) of the facility with potential of major accidents may have an interest and/or may be forced legislatively to insure against unlikely but potentially catastrophic losses and to contribute to the personal or public safety by minimisation of the losses. This in turn gives rise to obtain quantitative estimates of risks arising from rare failures with major consequences.

[1] See the categorisation of fire losses in [11]

Table 1. Information systems about accidents/incidents in various industries except the nuclear power industry

Name	Description	Organisation	Country	Ref
FACTS Failure and Accident Technical Information System	Worldwide information about 15,000 accidents (status 1992) with hazardous materials	TNO Netherlands Organisation for applied Scientific Research	NL	[12]
SONATA Summary of Notable Accidents in Technical Activities	Worldwide information about accidents with hazardous materials production, storage and transportation	TEMA A private company of ENI corporation	I	[13]
DCMR Data Base with Events with the Rijmond Process Industry	Information about a wide range of accidents/incidents in the industrial region Rijnmond (the Netherlands)	Central Environmental Control Agency Rijnmond	NL	[14]
ITACA Industry and Transport Accident Catalogue	Fires and explosions case histories	TRR A safety engineering consulting firm	I	[15]
ISPELS	Information about incidents with pressure vessels	Central Institute for Health and Safety Administration	I	[15]
not reported	Detailed case histories of onshore and offshore accidents/incidents	Health and Safety Executive (HSE), Department of Energy	UK	[15]
WOAD	Worldwide offshore accident data bank	VERITEC A consulting firm of the Det Norske Veritas corporation	N	[16]

The amount of historical data (meteorological, seismological, geological) about hazardous natural phenomena (hurricanes, tornadoes, floods, earthquakes, landslides, extreme snow loads) depends directly on the length of observation periods which, at least in some countries, may cover several decades. Quality of collected data and its applicability to structural analysis in an effort to manage risks related to the natural hazards may vary with individual phenomenon, however, the data situation on the whole should not be estimated as critical.

The data situation seems to be different if accidents and incidents induced by natural phenomena and man-made events in facilities of various types are considered. This situation can be evaluated looking at the availability and accessibility of accident data as well as its suitability to the formal models used in PRA.

3. Accident data

3.1. Availability

The availability of data about a wide range of accidents (incidents) is beyond question. Accidents and incidents including those involving damages to and destruction of structural components located in facilities are covered in a variety of ways. Information sources ranges from mainly non-professional mass-media reports to high-professional formal reports published widely by official organisations and "in-house" reports used, for example, for insurance purposes [12-14]. A considerable body of information has been collected in accident data banks. Most of them are specific to a particular type of facilities or individual industry, or else to particular classes of accident events. Some of the industrial accident data banks maintained by official and private organisations operating in countries EU[2] and EFTA[3] are briefly described in Table 1.

[2] European Union
[3] European Free Trade Association

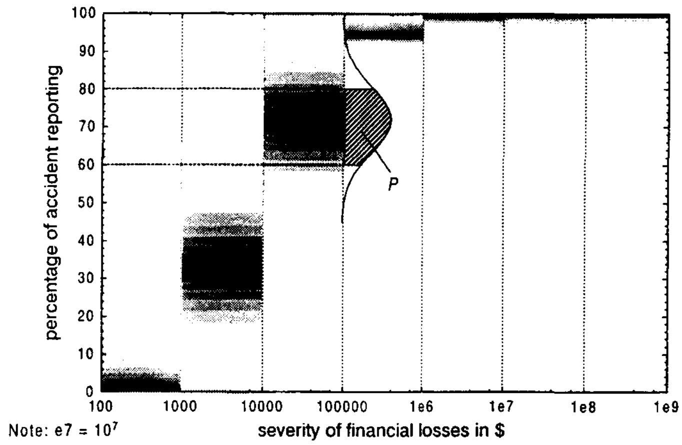


Fig 2. Hypothetical relationship between categories of financial losses and percentage of reported accidents (see also [12]; the area *P* shown in the figure is the probability that the percentage of the reporting of the accidents causing losses between $10 and $100 thousands lies between 60% and 80 %)

The availability of reported information on accidents depends directly on their seriousness. The major accidents are examined in detail and the reported information is made public, whereas the accidents placed on the opposite end of the scale of seriousness may not be reported at all [12, 13]. The intermediate field of the scale of seriousness is characterised by a finite percentage of reported accidents (Fig 2). Although a comprehensive investigation on the percentage of reporting of structural failures seems not to be available, one might expect that the character of the relationship "seriousness of failure - percentage of reporting" is akin to the one shown in Fig 2.

A very specific issue is the evaluation of information about structural failures from the viewpoint of risk management. Many structural failures in themselves are serious accidents causing severe consequences. Sources of information about structural failures vary widely in the reliability of evaluation [17]. The usefulness of a particular report of structural failure for the future application to the needs of risk management depends, among other things, upon how extensively has been covered the event sequence which led to the failure and/or the event sequence which followed it.

From the standpoint of risk management, the reporting of a structural failure is a relatively simple task if it was caused by a single and readily identifiable event of structural nature, say, human error in the design or construction and if the failure did not initiate a sequence of adverse events, such as impact on a pipe, release of hazardous material, ignition and lastly explosion. However, typical of severe accidents causing catastrophic losses are adverse event sequences starting frequently with non-structural events and involving structural failures or at least damages to structural components.

The most serious for both owner and insurer are the accidents when an adverse event sequence ends with partial or total collapse of building or engineering structure. The often cited examples of such accidents are loss of Piper Alpha platform and Flixborough explosion. The first accident occurred in 1988 with the offshore oil platform Piper Alpha in the North Sea and cost 167 lives lost and property damage in excess of $3 billions [18]. The accident started with a disturbance in production process and finished with the loss of platform, eventually due to a sequence of structural failures. In the second accident, the Flixborough Works of Nypro (UK) Limited were in fact destroyed in 1974 by a chemical explosion [19]. The blast originated with one of the chemical reactors of the facility. The accident killed 28 people and seriously injured 36 others. There was a widespread damage and some injuries outside the facility. Loses of structural nature involved damages of at least 1 821 houses and 167 shops and factories located in the proximity to the facility.

A recent example of the accident involving a serious structural failure is the disaster of a high-speed train near the German town Eschede in 1998 [20]. The accident was initiated by a relatively simple failure of a steel ring mounted on a wheelpair and ended with a derailment of several carriages at the speed of about 200 km/h. The impact of two derailed carriages destroyed the bridge crossing the railway at the side of the catastrophe. The bridge superstructure fell down on a derailed carriage, what made difficult to carry out a part of rescue work. In this accident 98 people were killed and 60 seriously injured.

Post-mortem investigations of severe accidents should and did include analysis of structural events, however, the investigations may be much more complicated and complex in their purposes and problems than an insulated reporting of immediate causes and character of structural failures that occurred in course of the accidents. An extensive research of coverage of structural events in the post-mortem investigations and other reports of accidents appears not to be available. On the other hand, results of analysis of the whole of structural failures are usually presented in such a generalised form that it is difficult to find out much of information which could be of interest in studies of a particular type of accident.

Widely published and cited results of analysis of structural failures cover mainly causes and to a lesser extent character of structural failures. Consequences receive little attention if any. Failure data processed to such a form are of little practical use when considered in the context of risk management, because information about consequences rather than causes of structural failures govern the attitude of society and insurers to risks arising from the failures. As an example one can refer to the results of investigation of 800 structural failures reported by M. Matousek and J. Schneider in 1976 and later reprinted in part in [17, 21, 22].

In the Matousek's analysis, consequences of structural failures are divided into two broad categories according to causes: consciously accepted hazardous events (accepted risk) and human errors (Table 2). The latter category is then traced back to the final causes which are seen as human unreliability (Table 3). One more categorisation is given in the Table 4 and refers to the way of consideration of hazardous influences on structures. This categorisation can be seen as a special case of the one from Table 2.

Judging from the results given in Tables 2 through 4, one can say that structural failures due to the abnormal loads[4] imposed on structures in the course of severe accidents or during extreme natural phenomena could fall into both of the categories "accepted risk" and "human errors". As long as the designer (owner) was aware of the possibility of abnormal loading conditions, they may be seen as "accepted risk". On the other hand, an incorrect or insufficient consideration of an abnormal load due to lack or scarcity of statistical data and/or uncertainty in the modelling related to the loading process or structural response to the load may be treated as "human error" if it leads to a structural failure.

As regards the structural failures occurring under normal loading conditions and caused by human errors, one can say with a fair degree of confidence that the theoretical simulation in an effort to estimate probabilities of such failures could not yield reliable results as yet. Although structural failures caused by human errors are dominant in both percentage of cases and total amount of consequences, the attitude of insurance industry to the quantitation of risks arising from such failures and thus the attractiveness of theoretical simulation in the face of underwriters remain to be elucidated. At the moment one can only state that human errors committed during design or construction and causing structural failures under normal loading conditions are not excluded in some standard polices of building insurance as cause of losses [10]. Consequently, the insurance could have an interest in the theoretical simulation, provided that it is carried out by verified models and backed by sufficient amount of data.

At the present a considerable amount of data on human unreliability is available, and several databases are reported in literature [23]. However, the databases are often applicable only to specific industries, such as nuclear power industry or chemical and process plants.

Another conclusion following from a formal consideration of the percentages given in Tables 2 and 4 is that in about three quarters of cases the risk management will have to deal with the structural failures caused by "human errors". However it is impossible to conclude from these tables as well as other categori-

[4] See the definition of normal and abnormal loads in [5]

Table 2. Two categories of causes of structural failures[a]

Cause of failure	Percentage of cases	Percentage of total cost of damage	Percentage of harm to people
Consciously accepted hazards (accepted risk)	25	10	15
Human errors	75	90	85

[a] All percentages sum vertically.
Source: [21]

Table 3. Human unreliability as source of structural failures[a]

Type of error	Percentage
Ignorance, thoughtlessness, negligence	35
Insufficient knowledge	25
Underestimation of influences	13
Forgetfulness, errors	9
Reliance on others without sufficient control	6
Objectively unknown situations	4
Other reasons	8

[a] All percentages sum vertically.
Source: [22]

Table 4. Consideration of hazardous influences[a]

Way of consideration	Percentage of cases	Percentage of total cost of damage	Percentage of harm to people
Not considered	22	27	22
Incorrectly considered	26	25	29
Not considered and incorrectly considered	4	12	6
Insufficiently considered	16	8	3
Considered as accepted risk	22	8	10
Unknown way of consideration	10	20	30

[a] All percentages sum vertically.
Source: [21]

sations reprinted in [21] how many of the 800 failures considered in the Matousek's analysis occurred in course of severe accidents or initiated such accidents, or at least imposed serious financial consequences as in the case of the relatively simple failure of Kufstein bridge which led to a long-time break-down of one of the traffic systems crossing the Alps [24]. A similar lack of detailed coverage of circumstances of structural failures in other broad surveys makes them of limited utility as source of information about accidents involving structural events (eg data on structural failures in [17]).

A more informative source of accident data are surveys of failures of a particular type of engineering structures, especially those which usually impose severe consequences in case of failure. Taken alone, the severe consequences require their coverage in such degree of thoroughness which is necessary for owners, insurers, local society and other parties involved in mitigation and retention of the consequences. The severity of consequences determines that in many instances they are related to structural failures in failure surveys which are compiled usually by engineers and mainly with the aim to improve the design of prospective structures or, conversely, to upgrade the existing structures which have a high potential of failure. Examples of such failure surveys are collections of reports about destruction of and damage to dams analysed in [25, 26].

3.2. Accessibility

Further problem related to accident data is the accessibility of available data. It is an organisational and legal problem. On the other hand, the inaccessibility of data on accidents suffered in facilities of a particular category becomes a technical problem because it makes the risk analysis of an individual facility belonging to this category into a purely theoretical forecasting. It would be an ideal situation to have at hand all relevant data about the accidents which occurred to date and were reported world-wide before starting to carry out the risk analysis of the facility.

The importance of the maximum possible accessibility of accident data follows from the fact that accidents, especially major ones, are rare events, particularly if a specific type of accidents or accident scenarios is considered. The industrial data banks listed in Table 1 are reported as having a high degree of accessibility. Judging from references cited in the table, the data banks can provide the possibility to obtain a considerable amount of generic data on accidents which are possible in the facility under analysis.

Brief mention should be made of the European Reliability Data Bank Association EuReDatA when speaking about the accessibility of accident data. The Association was founded in 1973 and is aimed to facilitate and harmonise the development and operation of reliability, unavailability or event data banks of its members [27]. The EuReDatA membership provides a possibility to exchange data between organisations participating in the Association. Some of them are listed in Table 1. So far we know no Lithuanian organisation is involved in the Association although since 1988 it is opened to potential members in countries not belonging to EU and EFTA. The list of EuReDatA members (data suppliers) is rather large and wide variety of different data is, at least in principle, accessible to them. However, it is difficult to judge from the presentations of EuReDatA in literature how useful would be an institutional participation for the structural engineers belonging to the team which has to carry out the risk analysis of a particular facility.

A considerable amount of information on accidents collected by individual industries as well as industrial and insurance companies is usually inaccessible to third parties [15]. The situation with accident data is comparable in respect of accessibility with the general state of affairs in the field of reliability data. The dominant tendency is to treat reliability data as business data [24]. Data owners keep facility specific reliability data as confidential company property. Moreover, it is stated, that the facility management tends to conceal minor accidents because there is a widespread belief that such accidents bring dishonour and negative public attitude [13]. Only a few initiatives, such as EuReDatA, demonstrate a completely opposite attitude to this tendency. A clear exception to the general practice is also data available in obligatory accident reports to authorities. It would reasonable to expect that such data are in great part accessible.

The regulations for accident reporting vary from one country to another, especially when observed over a relatively long time period during which the accidents occurred. However, accidents involving serious structural failures will most likely fall to the category under consideration in almost every country.

3.3. Suitability

Suitability of collected accident data for the theoretical models used in PRA and, conversely, verification of a particular theoretical model chosen to assess risks of the facility under investigation are problems of no less importance that the ones of data collection and processing as well as choosing or adaptation of available theoretical models. According to this, the problem of suitability may be approached on two sides, namely, considering available data collections and demands of theoretical models for data. Any exhaustive discussion on this subject is impossible within the limits of a single paper, however some remarks related to structural aspects of PRA can be made here.

Large accident data collections, like FACTS, SONATA and DCMR (Table 1), contain information on causes, courses and consequences of a great quantity of accidents in facilities of various type. If the facility to be analysed is not of unique character as a whole or at least in its principal subsystems, there is high probability to find information which could be useful to obtain or verify results of the qualitative part of PRA, namely identification of initiating events, possible failures and their consequences. The search on such information can be highly efficient if reports about accidents are partially coded and stored in the computerised form, as in the case of the three data banks listed above [12-14].

The coding of accident reports allows also to find out without difficulty adverse event sequences embracing imposition of abnormal loads on structural systems located in the facilities of interest. For example, case histories of over 80 LPG[5] storage accidents were fixed in the data bank SONATA (status 1986) [13]. The following percentages of accident types were obtained on the basis of collected information:

Flash fire	41 %
BLEVE[6]	21 %
UVCE[7]	19 %
CVE[8]	19 %

Further information stored in SONATA embraces causes of emission, modes of ignition and consequences of the accidental events just listed. The data bank FACTS contains information on 735 accidents of LPG storage, transportation, processing and other activities (status 1992) [12]. Such considerable amount of data collected in both accident data banks makes probable to find information suitable for the assessment of risks of a particular structural system exposed to hazards inherent in LPG facilities of the type in question. Clearly, the number of reported accidents which can yield information relevant to a particular situation of building exposure may be much lesser compared to the total number of accidents which occurred in LPG facilities and have been coded in SONATA, FACTS and other data banks.

The suitability of available accident data may also be evaluated considering the data situation in such a manner as it is done by applying the procedure known in the reliability engineering as "precursor study" (eg [28]). According to the approach used in this procedure, the consideration should be taken not only of the adverse event sequences that result in imposition of abnormal loads on structural system and are relevant to the situation of building exposure being considered. The data on many of the adverse event sequences which fortunately did not lead to destruction of buildings and were stopped earlier may also be suitable for both qualitative and quantitative parts of PRA.

Events initiating the "early stopped" sequences resulting only in minor failures from structural point of view may be frequent ones as compared to major accidents involving destruction of buildings. Consequently, during the operation of many kinds of facilities there may be collected representative samples which could allow to estimate "accurately" frequency of an initiating event and certain of probabilities of "chance forks" in event tree and/or basic events in fault tree(s) constructed for the initiating event in the preceding qualitative part of PRA.

Both accident data collected as operating experience and theoretical modelling of accident courses by means of PRA could allow to predict frequencies and intensities of abnormal loads as well as degree of damage to structural systems caused by the loads. Of course, it remains to be elucidated in detail how particular data collections are suitable to obtain reliable predictions regarding the abnormal loads and their influence on buildings. An investigation of individual data collections with respect to the needs of structural analysis is outside the scope of the present paper, however.

The investigations of data collections published in literature restrict themselves mainly with simple classifications of accidents and may be so much useful for the structural engineer as far as structural events or at least imposition of abnormal loads are described in them (eg [14, 29]). For example, an analysis of 700 accidents in the chemical industry selected from the data bank FACTS has shown that almost 80 % of all selected accidents result into release of chemicals [29]. In about 70 % of the accidents a release was followed by a fire and explosion (Fig 3). However, consequences of the explosions (fires) and structural events following them are not analysed.

Further feature of available accident data and to a large degree reliability data and unavailability data is its scarcity with which one have to deal in almost all practical applications of PRA. The situation when there is only a limited amount of data at hand to estimate the majority of input parameters of various methods used in PRA is described by the risk community as normal rather than abnormal one.

[5] Liquified petroleum gas
[6] Boiling liquid expanding vapour explosion
[7] Unconfined vapour cloud explosion
[8] Confined vapour explosion

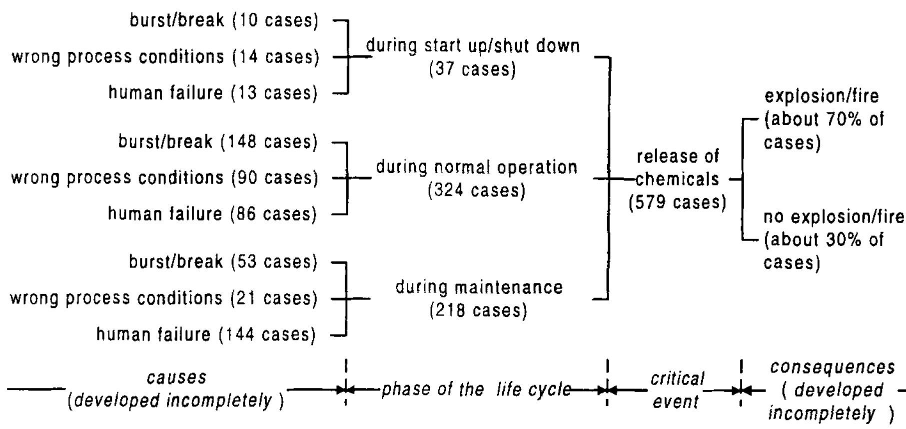


Fig 3. Categorisation of accidents including release of hazardous chemicals and selected from the data bank FACTS [29]

The main recipe for tackling the problem of limited statistical data named also "hard" data is to integrate the data with judgement (expert opinions) concerning inputs in PRA methods and thus their outputs. Up to now, bayesian and fuzzy methods (approaches) have been applied by PRA in particular and by the reliability theory in general to accommodate subjective information and to deal with the analyst's uncertainty induced by the hard data available in limited amounts [4, 7, 30].

Several procedures for representation of the analyst's uncertainty in inputs and its propagation to outputs of PRA methods were proposed [3, 4, 7]. The procedures allow to cope with the problem of limited data, although they can not replace the missing statistical data as such.

The impression is that the published work devoted to the modelling of uncertainty induced by the limited hard data is concerned mainly with mathematical maters and not with the analysis of the data. It seems likely that the interrelationship between quality of accident data available in the form of small samples, on the one hand, and uncertainty with respect to model parameters to be estimated using these samples, on the other, has received little attention. Here, by the quality of accident data is meant its correctness, homogeneity, suitability to be applied in situations similar but not identical to those which generated the data.

The scarcity of accident data as well as reliability and unavailability data may cause that in many practical cases an integration of PRA with the probabilistic structural analysis will be impossible without applying the modelling of analyst's uncertainty to the probabilistic structural analysis.

4. Concluding remarks

The data situation in the probabilistic risk analysis (PRA) was considered having an eye to integrate this methodology with the probabilistic structural analysis (PSA).

Bearing in mind the fact that structural systems located in facilities usually fail under abnormal service conditions first of all in course of severe accidents, the situation of the accident data including information on structural failures was analysed in the paper. The availability, accessibility and suitability of collected accident data were discussed. A detailed investigation of individual collections of the accident data was not the aim of the paper.

Two types of structural failures should be distinguished from the viewpoint of PRA. On the one hand, structural systems may fail under generally normal service conditions, and failures occur mainly due to human errors in the design, construction or use of the systems. These failures in themselves may be serious accidents or may initiate adverse event sequences which lead to such accidents. On the other hand, structural systems may fail under abnormal service conditions and first of all due to imposition of abnormal loads. In this case structural failures, especially major ones, appear usually close to the "end" or at the "end" of adverse event sequences and are important contributors to the consequences imposed by the accidents involving the failures. Of course, such categorisation of structural failures as events being of interest to PRA is not exhaustive, however, a consideration of both cases just mentioned makes possible to look at several important aspects of data situation in PSA and PRA. Several obvious conclusions suggest themselves from the discussion given in the previous sections.

Firstly, there is not a sufficient amount of data which could allow to apply in practice and above all else to verify reliability methods intended for the estimation of failure probability for a structure with the presence of human error. This makes difficult an estimation of probabilities of major structural failures considered as initiating events.

Secondly, large surveys of structural failures deal usually with causes and not consequences of the failures. Their circumstances are often described not well enough, if at all. Failure surveys of some individual types of structural systems, such as dams, are much more informative when considered from the standpoint of PRA.

Thirdly, there is collected a considerable body of information on the accidents which occurred in a variety of facilities. As may be inferred from the descriptions of large accident data collections, they can in many cases provide a possibility to extract a substantial amount of data relevant to the typical situations of the exposure of structural systems. Such data may be interesting to all participants of the risk management process and primarily to the facility's owner and the property insurer. In the opinion of the structural engineer the extracted accident data is so much valuable as far as it allows to estimate likelihood and parameters of the abnormal loads which may be imposed on structural system under consideration in course of an accident. This, of course, requires to process the raw accident data as well as reliability and unavailability data to the point where an application of PSA becomes possible.

Finally, the author's impression is that the gap between the raw accident data and theoretical models developed in PSA still remains to be bridged for many types of accidents and structural systems. One way to do it is, of course, an integrated application of PSA and PRA.

References

1. Risk management: practical techniques to minimise exposure to accidental losses // The Institute of Cost and Management Accountants, Prep. by J.Glanvill, London: Jardine Glanvill (UK) Ltd, 1986. 56 p.
2. R.Flanagan, G.Norman. Risk management and construction. London etc.: Backwell Scientific Publ., 1993. 208 p.
3. H.Kumamoto, E.J.Henley. Probabilistic risk assessment for engineers and scientists, 2nd ed. New York: IEEE Press, 1996. 597 p.
4. R.E.Melchers. On the treatment of uncertainty information in PRA // Proc. of Int. Conf. "Probabilistic Risk and Hazard Assessment". Ed. by R.E.Melchers and M.G.Stewart, Rotterdam: Balkema, 1993, p. 13-26.
5. C.Sundararajan(Raj), V.VoTroung. Probabilistic structural mechanics in system and plant risk assessment // Probabilistic Structural Mechanics Handbook. Ed. by C.Sundararajan, New York: Van Nostrand, Reinhold, 1993. p. 188-210.
6. M.J.Baker, R.J.Graves, M. Kearney. A methodology for risk management in civil, mechanical and structural engineering // Proc. of Conf. "Risk Mangement in Civil, Mechanical and Structural Engineering", London, 22 February, 1995, Ed. by M.James, London: Thomas Telford, 1996, p. 67-85.
7. T.Aven, W.Rettendal. Bayesian frameworks for integrationg QRA and SRA methods // Structural Safety, Vol 20, 1998, p. 155-165.
8. P.Mackenzie. ANCOLD and its interest in risk assessment // Proc. of Seminar on Acceptable Risks for Extreme Events in the Planning and Design of Major Infrastructure, Sidney, 26-27 April, 1994, Ed. by P.Henrichs and R.Fell, Rotterdam: Balkema, 1995, p. 1-12.
9. B.G.Roylett. Risk financing in planning, design and operation of major infrastructure // Proc. of Seminar on Acceptable Risks for Extreme Events in the Planning and Design of Major Infrastucture, Sidney, 26-27 April, 1994, Ed. by P.Henrichs and R.Fell, Rotterdam: Balkema, 1995, p. 61-69.
10. F.A.Sundheim. How to insure a business. Santa Barbara, California: Venture Publishing, 1988. 256 p.
11. G.Ramanchandran. Extreme value theory // SFPE Handbook of Fire Protection Engineering. P.J.Nenno (Editor-in-Chief). Quincy, MA: National Fire Protection Association, 1988.
12. L.J.B.Koehorst. FACTS - a data base for industrial safety // Reliability Data Collection and Analysis. Ed. by J.Flamm and T.Luisi. Dordrecht etc.: Kluver, 1992, p. 89-104.
13. E.Galatola et al. SONATA: An accident data base for industrial activities and transport. Scope, organisation and main results // Proc. 5th EureDatA Conf. "Reliability Data Collection and Use in Risk and Availability Assessment". Ed. by H.J.Wingender. Berlin etc.: Springer-Verl., 1986, p. 146-157.
14. D.Goos et al. Data bank of events with the Rijmond Process industry // Proc. 5th EureDatA Conf. "Reliability Data Collection and Use in Risk and Availability Assessment". Ed. by H.J.Wingender. Berlin etc.: Springer-Verl., 1986, p. 137-145.
15. P.Bockholts et al. A survey on industrial accident data bases // Proc. 5th EureDatA Conf. "Reliability Data Collection and Use in Risk and Availability Assess-

ment". Ed. by H.J.Wingender. Berlin etc.: Springer-Verl., 1986, p. 130-136.

16. Worldwide Offshore accident databank: WOAD statistical report 1988. Statistics on accidents to offshore structures engaged in oil and gas activities in the period 1970-87. Høvik: Veritec, 1988. 143 p.
17. R.E.Melchers. Human errors and structural reliability // Probabilistic Structural Mechanics Handbook. Ed. by C.Sundararajan, New York: Van Nostrand, Reinhold, 1993, p. 211-237.
18. M.E.Paté-Cornell. Learning from Piper Alpha accident: a postmortem analysis of technical and organizational factors // Risk Analysis, Vol 13, No 2, 1993, p. 215-232.
19. R.B.Jones. Risk-based management. A reliability-centred approach. Houston etc.: Gulf Publishing Comp., 1995. 282 p.
20. Heimsuchung im High-Tech-Land // Der Spiegel, Nr. 24, 1998, 22-31 S.
21. J.Schneider. Sicherheit und Zuverlässigkeit im Bauwesen. Zürich, Stuttgart: VDF, Teubner, 1995. 193 p.
22. M.Matousek. A system for a detailed analysis of structural failures // Proc. of 3rd Int. Conf. on Structural Safety and Reliability ICOSSAR'81. Ed. by T.Moan and M.Shino-zuka, Amsterdam etc: Elsevier, 1981, p. 535-544.
23. M.G.Stewart. Human error, error control and human reliability // Proc. of Int. Conf. "Integrated Risk Assessment". Ed. by R.E.Melchers and M.G.Stewart, Rotterdam: Balkema, 1995, p. 73-82.
24. H.J.Wingender. Needs and use of data collection and analysis // Reliability Data Collection and Analysis. Ed. by J.Flamm and T.Luisi. Dordrecht etc.: Kluver, 1992, p. 15-43.
25. E.S.Kalustian. Destruction and damage of concrete dams on rock foundations. Moscow etc.: AO VNIIG Publ., 1997. 188 p.
26. L.DeKay, G.H.McClelland. Predicting loss of life in cases of dam and flash flood failure // Risk Analysis, Vol 13, No 2, 1993, p. 193-205.
27. H.Procaccia. Presentation of EuReDatA // Reliability Data Collection and Analysis. Ed. by J.Flamm and T.Luisi. Dordrecht etc.: Kluver, 1992, p. 1-13.
28. O.Klingmüller, U.Bourgund. Sicherheit und Risiko im konstruktiven Ingenieurbau. Braunschweig, Wiesbaden: Vieweg, 1992. 369 p.
29. L.J.B.Koehorst. An analysis of accidents with casualties in the chemical industry based on the historical data // Reliability Data Collection and Analysis. Ed. by J.Flamm and T.Luisi. Dordrecht etc.: Kluver, 1992, p. 161-180.
30. O.Ditlevsen, H.O.Madsen. Structural reliability methods. Chichester etc.: Wiley, 1996. 372 p.

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DUOMENŲ SITUACIJA TIKIMYBINĖJE RIZIKOS ANALIZĖJE, TAIKANT JĄ KONSTRUKCINĖMS SISTEMOMS

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S a n t r a u k a

Straipsnyje aptariamas duomenų poreikis ir sukaupti duomenys, kurių reikia, norint integruoti tikimybinę rizikos analizę su tikimybiniu konstrukcinių sistemų (pastatų, statinių, tiesinių) skaičiavimu. Pagrindinis dėmesys skirtas duomenims apie avarijas įvairiuose pramoniniuose objektuose ir statybinių konstrukcijų avarijas.

Pramoninių objektų konstrukcinės sistemos gali būti pažeistos dėl pavojingų gamtinių reiškinių ar žmogaus veiklos padarinių. Nuostoliai, sukelti šių veiksnių, gali būti vertinami kaip eksploatacinės išlaidos arba juos atlygina draudikas. Draudimo problema yra lengvai išsprendžiama, jeigu draudikai turi pakankamai duomenų apie anksčiau patirtų nuostolių dydį ir dažnį. Tačiau sunkios avarijos pramoniniuose pastatuose įvyksta retai ir duomenų apie patirtus nuostolius būna sukaupta mažai. Tokiu atveju riziką, t. y. nuostolius ir jų patyrimo dažnį galima prognozuoti tikimybinės rizikos analizės metodais.

Matematiniams tikimybinės rizikos analizės metodams taikyti reikia turėti statistinių duomenų. Šie duomenys turi atspindėti pramoniniuose objektuose įrengtų techninių sistemų patikimumą ir parengtumą. Kita svarbi duomenų rūšis yra informacija apie avarijas, įvykusias įvairiuose pramoniniuose objektuose. Šie duomenys yra būtini, įtraukiant į tikimybinę rizikos analizę galimus konstrukcinių sistemų atsakus. Avarijų ar stichinių nelaimių metu konstrukcinės sistemos būna veikiamos tokių apkrovų, kurios nenumatomos projektuojant šias sistemas.

Avarijų duomenys kaupiami įvairiai. Didžiausi duomenų rinkiniai yra duomenų bankai. Straipsnyje trumpai apibūdinti žinomiausi duomenų bankai, sukurti Vakarų Europos šalyse ir dažnai aprėpiantys visame pasaulyje įvykstančias avarijas. Pavieniai bankai detaliai nenagrinėjami. Straipsnyje analizuotos sukauptų duomenų prieinamumo bei tinkamumo vertinant konstrukcinių sistemų patikimumą problemos.

Kitas svarbus duomenų šaltinis yra informacija apie konstrukcijų avarijas. Straipsnyje trumpai aptariami specialiojoje literatūroje paskelbti duomenys apie statybinių konstrukcijų avarijas ir šie duomenys vertinami tikimybinės rizikos analizės aspektu. Nustatyta, kad bendro pobūdžio statybinių konstrukcijų avarijų apžvalgos yra mažai naudingos tikimybinei rizikos analizei. Tose apžvalgose daugiausia nagrinėjamos avarijų priežastys, o ne pasekmės, avarijų aplinkybės detaliai neaprašomos. Rizikos analizei naudingesnės yra specialiųjų konstrukcinių sistemų, pavyzdžiui, didelių užtvankų, avarijų apžvalgos. Jose pateikiama informacija yra daug detalesnė ir aprėpia ne tik konstrukcinio pobūdžio įvykius, bet ir, pavyzdžiui, nuostolius, patiriamus įvykus avarijoms.

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