Pre-accidental situations highlighted by RECUPERARE method and data

Naoëlle MATAHRI

Institut de Radioprotection et de Sûreté Nucléaire

DSR/SEREP

BP 17 92262 Fontenay-aux-Roses

Abstract:
RECUPERARE method has been developed for operating feedback analysis and built on the French Human Reliability Analysis (HRA) principles. It is used to study the causes of human errors or technical failures occurred in French PWRs and the recovery process of events. Based on an event classification (6 categories) model according to the nature of the link between failure and recovery, the identified and recorded data are:

- the causes of the defects (technical, human, organizational) and the context in which they appear;
- the factors of the recovery performance (depending on technical and organizational aspects);
- a chronological analysis, designed to collect delays between failures and their detection/recovery for each event.

About 3600 events reported in French PWRs (1997-2003) had been reviewed through this model. Initially, the weight of factors and the most important factors, which influenced the detection and recovery delay, are defined. For this purpose, the regression Partial Least Square (PLS) is used. Then, to link RECUPERARE results with pre-accidentals data, conditional probabilities of events linked between them by a cause and effect relationship are calculated. For this, the Bayesian method with the Bayesian network is built with the PLS obtained results and applied. This constitutes a first approach to take into account in HRA the human and organizational factors highlighted by operating feedback.

1 INTRODUCTION

The first IRSN PSA model was established since 1990. Pre-accidental conditions, initiator and post initiator operation management are the main three parts of its structure. A HRA model is used to produce the figures of human reliability, based on data obtained by simulator and expert judgment. Probabilities to recover an existing failure according to the detection means, before the initiator, are the main data.
The RECUPERARE data are obtained from the 3600 EDF event reports (1997-2003). EDF writes these event reports when some safety significant, technical or human failures occur on a nuclear plant. IRSN analyses them with the RECUPERARE method and the descriptors of each events are recorded in a database.

This analysis can help experts to update the pre-accidentals data used in EPS.

To achieve this purpose, several steps are necessary:

1. to determine the various factors of events reported in the RECUPERARE data base, which influence the detection and recovery delay;

2. to find the Bayesian network which describes the connections between these RECUPERARE fields (network nodes), with a qualitative point of view;
3. to evaluate the network parameters which quantify the connections between the RECUPERARE fields.

The result of these various studies is the definition of a Bayesian network, which allows the calculation of various conditional probabilities, taking into account human and organizational factors from operating feedback, by means of situations contained in the database RECUPERARE.

2 FACTORS INFLUENCING THE DETECTION AND RECOVERY DELAY

2.1 Technique of analysis

Which descriptors can explain the detection delay of a failure and the recovery delay in an event?
Using RECUPERARE method, for each event, 140 descriptors (fields) may be fulfilled with a mode chosen among others; only some fields are pertinent to describe one event (50 in average). For example, some fields can be enumerated: categories of event, detection means, context of event emergence (temporal context, activity…), error actor, detection actor, recovery actor, nature of errors, erroneous procedure, Man Machine Interface quality, nature of failure, field “dependence” (this field is used in the instances of dependency between the default and the recovery for activities, crews and actors), organizational aspects of events (communication, management…). Examples of modes, for detection means, can be: alarms, check list of verification, periodic test, etc…

The statistical analysis method carried out to establish those relationships between delays and descriptors is regression PLS. Equations modeling these delays according to modes of the fields are built. The weight of a mode on a delay is thus easily interpretable by a coefficient associated with this mode.

Why this method is selected?
This method is effective when facing to the presence of a great number of missing values and it is our case. It allows without difficulty to treat the cases where the number of predictors (number of events) largely exceeds the number of observations (characteristic of the event). The results given by this method is a hierarchy of the modes according to their role on the detection or recovery delay. This helps to select the most important ones.

2.2 Modeling of detection delay

The studied sample comprises 2565 events. The detection time is indicated in 60% of the cases (1543 events).

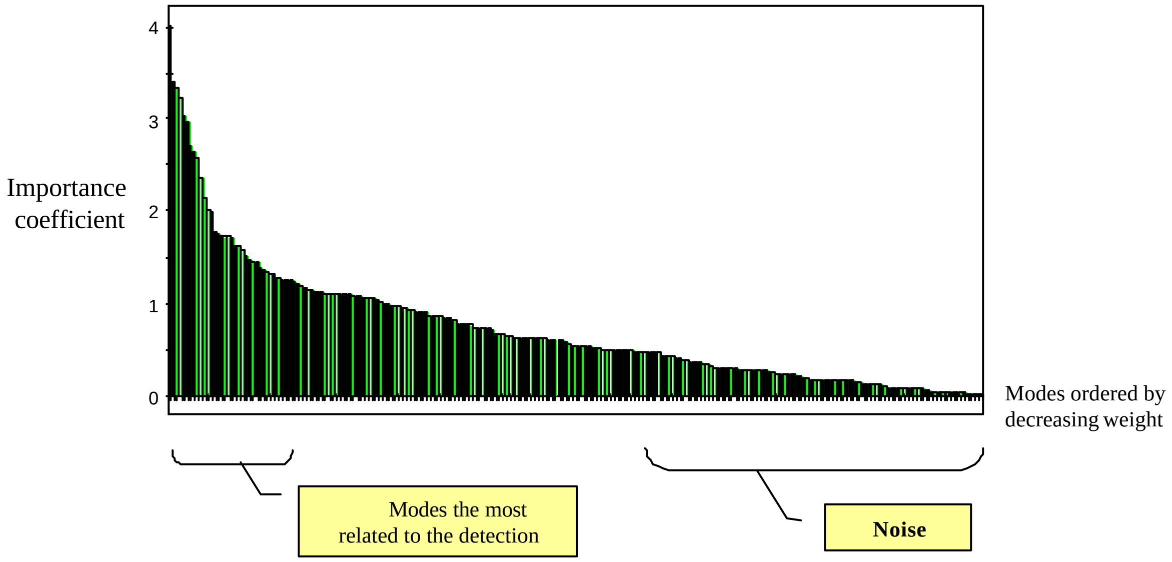

Figure 1. Weight of the modes in the modeling of the detection time

The results provided by modeling are:

- the strong influence of the category of event,
- the strong influence of the detection means,
- the strong influence of the field “dependence” (this field is used in the instances of dependency between the default and the recovery for activities, crews and actors),
- the influence of the context of event emergence (temporal context, activity…)
- the influence of error actor and detection actor,
- the influence of the individual errors,
- the influence of organizational aspects of events (communication, management…).

For example, the weights associated with the modes “same activity” and “same actor” amount respectively 1.53 and 0.57. The ratio between these weights amounts to 2.7. This means that the detection time for an event with the mode “same activity” is about 2.7 times longer than for an event with the mode “same actor”.

3 LINK WITH PRE-ACCIDENTALS DATA

The previous study allowed us to define the fields, which influence the detection delay. For each field, the study determined a hierarchy of the modes according to their role on the detection delay.
These fields are used in the construction of a Bayesian network.
This network is important to identify the relation between each field and to calculate the conditional probability at each node. For this study, the hypothesis “the success or not of the detection in 30 minutes” is taken in order to determine the conditional probabilities and the non-detection probabilities. The detection time is fixed at 30 minutes because we consider that the operator must detect a red alarm in less than 30 minutes.
Moreover, the sample of RECUPERARE situations needs to be completed by simulated situations in order to have all possible situations according to the selected fields in the network. Thus, we obtain an exhaustive sample of this type of situations.
For each defined situation in the considered sample, the network provides the probability of occurrence and the non-detection probability in 30 minutes.

3.1 The network

In the French PSA, the HRA model for the pre-accident part asserts: If a human failure exists before that the initiator occurs and if a red alarm appear, the non-recovery probability of error is estimated to 10^{-3} (expert judgment). How can we compare this estimation to the delays founds in the events and reported in the RECUPERARE database?
To try to make a link between this situation and operating feedback, the studied sample contains the events with two characteristics: they involve at least a human error and the detection mean is a red alarm. Their non-detection probability in time is calculated with Bayesian approach.
Initially, the authors determined a Bayesian network. This consists in searching couple of fields, which are independent conditionally with a third field (order 1 conditional independence). For this, experts chose fields among others, which influence the delay: fields obtained by PLS regression. Thus, the network comprises the connections considered to be the strongest ones. Non-directed segments represent these connections. The experts' work then consists in directing the connections according to the desired convergent connections.
Moreover, the K2 algorithm gives a structure of the network by progressive learning. The authors retained some suggested connections.
The final network is the combination of the two structures.

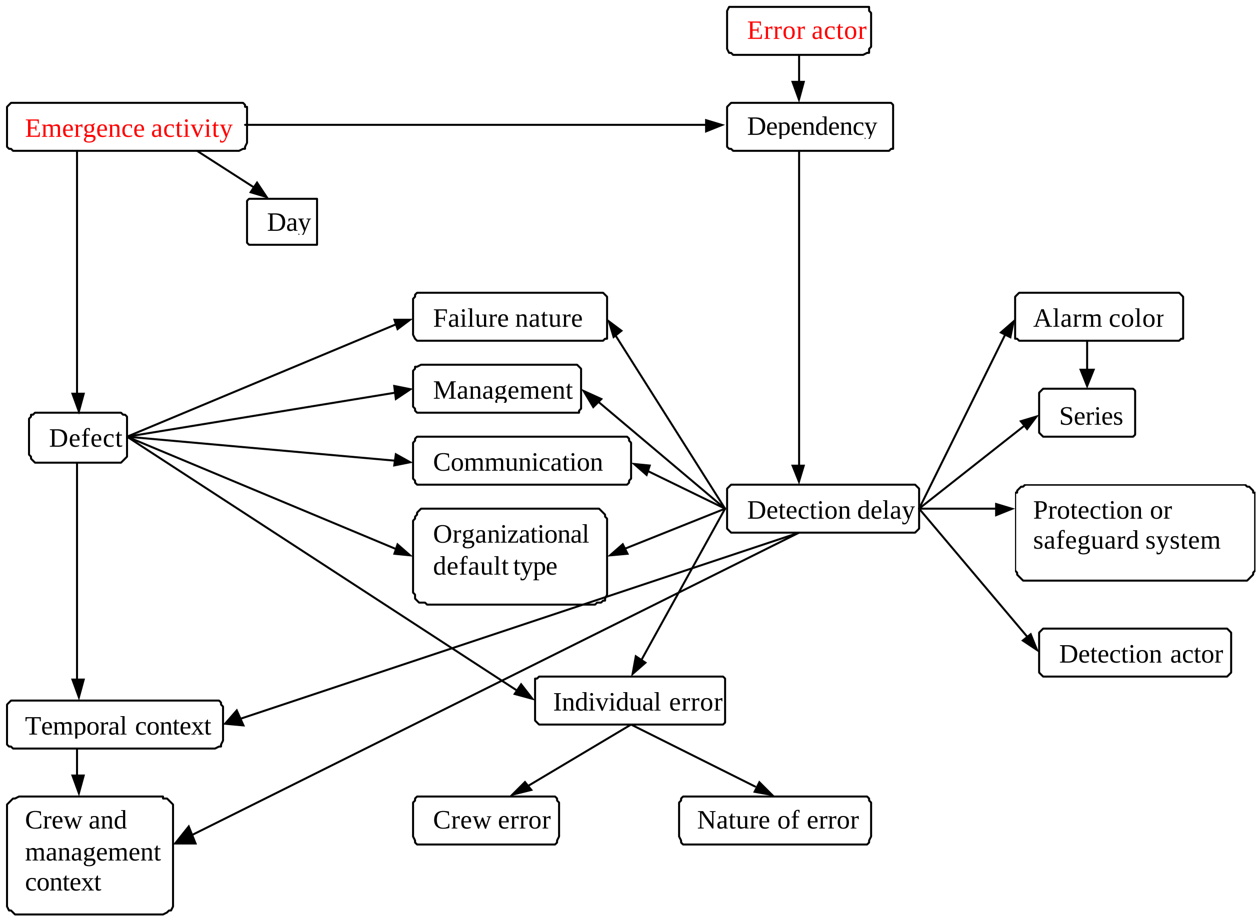

Figure 2. Final Bayesian network

3.2 Fields contributions to non-detection risk

In order to treat on a hierarchical basis the network fields according to their contribution to the non-detection risk, the authors calculate the non-detection probability of the event in 30

minutes fixing the mode of a field and the alarm color (red or different), all the other fields of the network not being indicated. The non-detection probability, according to the alarm color and each mode of the fields taken individually, is thus obtained.
For example, the non-detection probability of the event in 30 minutes for the various modes of "error" field is given by the following table.

Error \ Alarm color	Red	Other
Omission action	0.346	0.429
Inappropriate action	0.184	0.242
Commission action	0.135	0.181

Table 1. Non-detection probability according to some modes of "error" field for red and different alarms

If the "error" is an "omission action", the non-detection probability of the event is higher than if the "error" is a "commission action".

3.3 Non-detection risk

Two hypotheses are possible:

1. The non-detection probability is constant and thus does not depend on the event,
2. There are classes of events for which the non-detection risk is higher.

In the case of hypothesis 2, different classes of event with some specific characteristics of situation can be identified, and their frequencies can be determined. This is important because if some events are not very frequent, the non-detection probability is worth indeed the announced value, in average.
Indeed, if the situation is very improbable even if the non-detection probability is high, the non-detection risk is less important than when the situation is very probable and the non-detection probability is high.
A rigorous formulation of the non-detection probability (or non-detection risk) uses consequently two terms:

- The first term is the non-detection probability in a given situation (or event given). It quantifies the performance of the process of recovery.
- The second term is the probability of being in the situation. It quantifies the exceptional character or not of the situation.

The risk is defined as follows:

$$Risk = \sum_{\{situations\}} prob(non-\det ection / situation) \times prob(situation)$$

Three cases are possible:

1. The non-detection probability is low, the recovery process performance is thus high => the non-detection risk is very low.
2. The non-detection probability is high, the recovery process performance is thus low, and the situation is very improbable => the non-detection risk is very low.
3. The non-detection probability is high, the recovery process performance is thus low, and the situation is not rare => the non-detection risk is high.

These three cases are schematized below.

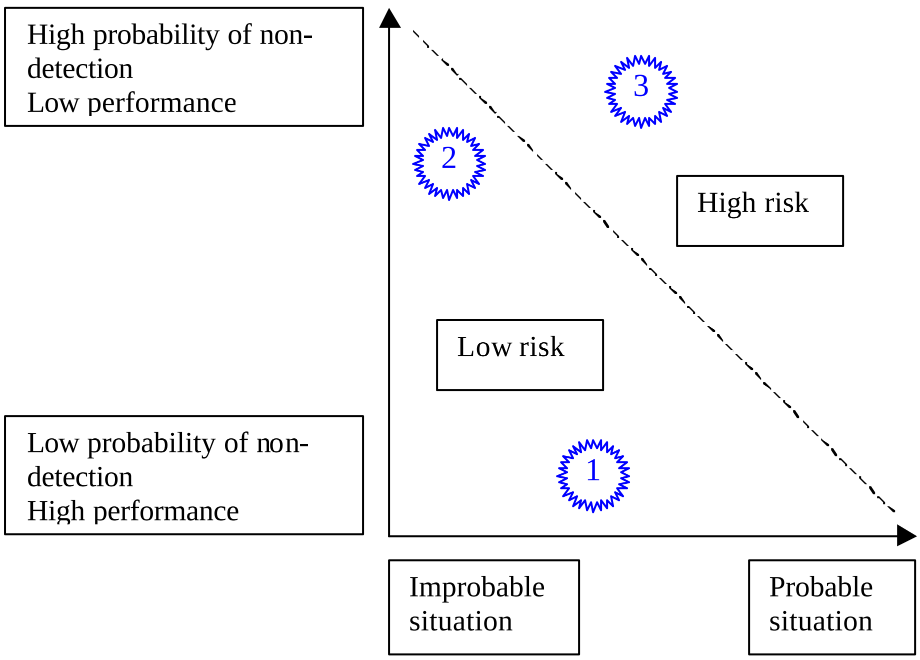

Figure 3. Schematization of the non-detection risk importance

Using the RECUPERARE data, the objectives are:

- To know the non-detection probability of the event for each possible situation,
- To calculate the probability of occurrence for the critical situations,
- To search the parameters of the recovery process (the various combination of selected fields) which can explain the low detection performance.

3.4 Analysis definition

The analysis is made as follows:

1. The red color for the field alarm is fixed,
2. The various recovery processes according to fields', which have an influence on the detection time, are simulated. All the possible combinations of the modes of these fields, each one representing a different recovery process, are obtained. For each one of these processes, the network provides the probability of occurrence of the process and the non-detection probability of the event in 30 minutes.
3. The other fields are supposed to be unknown.

The specified analysis represents the generation of 3456 events.

3.5 Histogram of the non-detection probability

On the sample of the 3456 simulated events, we obtain the same value of the non-detection risk than on the sample of the actual events given by RECUPERARE database.

The figure bellows gives the distribution of the numbers of simulated events according to the non-detection probability in 30 minutes.

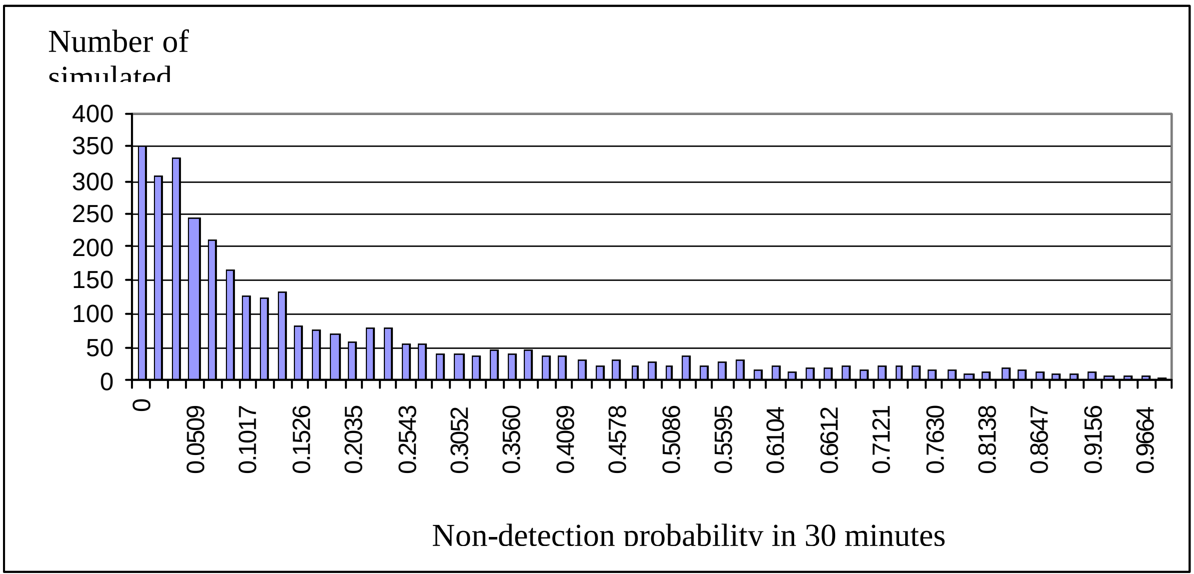

Figure 4. Number of simulated events according to the non-detection probability in 30 minutes.

These results enable us to answer various questions:

For example, which is the situation for which the non-detection probability is highest?

This situation is:

- "Same activity" for the "dependence" field: the error is done by a person or a crew and other person or crew, who continue the activity, has to detect the errors,
- A problem of control for the field "management": the management misses some controls,
- Several problems of communication for the "communication" field: lack of communication appear during the activity,
- Omission action for the human error: the person forget to do something,
- The detection actor is not an agent of the operating crew,
- And no start-up of the protection or safeguard system.

For this situation, the non-detection probability in 30 minutes is 0.983.

This example shows that probabilities calculated with the Bayesian network can represent what we learn with operating feedback: a worse situation is a situation with the coincidence of multiple small failures in organization or organization drift. The result is a bad performance in the detection and recovery actions.

4 CONCLUSION

This study is a first step in the construction of the link between RECUPERARE results and pre-accidentals data.
The next steps are to improve of the Bayesian network in order to take into account new dependences between the RECUPERARE fields, to better characterize the studied sample in order to determine the various families which have the same non-detection probability, and to do the same analysis for other detection means.

5 REFERENCES

[1] H. Procaccia, and M-C SUHNER “Démarche bayésienne et applications à la sûreté de fonctionnement” éditions Hermès, Lavoisier.

[2] P. Naïm, P-H Wuillemin, P. Leray, O. Pourret and A. Becker “Réseaux bayésiens” éditions Eyrolles.

[3] Proccedings of “ Retour d’expérience: les réseaux bayésiens, outils d’analyse et de structuration” ImdR-SdF, 2005.

[4] Rapport IPSN/DES 371 “Modèle et méthode RECUPERARE”

[5] IAEA-CS12/96, December 1996, Single Human failures in Nuclear Power Plants: a Human factor approach to the event analysis, report of a consultant meeting organized by the international atomic energy agency in Vienna 25-29 March 1996

[6] Intention and error: their role in responsibility studies, Jacques Leplat, in " Revue européenne de Psychologie Appliquée" Vol 43 N° 4 page 279-287

[7] “Looking for errors of omission and commission or the hunting of the snark revisited”, E. Hollnagel,.1999

[8] “Method for quantifying human and organizational factors in accident management, using Decision Tree, The HORAAM method”, G. Baumont and al RSSE Review, Elsevier, October 2000

[9] “RECUPERARE, a model of event including human reliability in nuclear plants”, G. Baumont, N. Matahri & JL. Roy, p251-257, Proceedings of PSAM5, Osaka 2000

[10] “Omission, commission and weight of factors highlighted by RECUPERARE method”, N. Matahri, G. Baumont, P. Quentin, p905-911, Proceedings of PSAM6, Puerto Rico 2002