# THE DEPENDENCE LEVEL ANALYSIS BETWEEN THE HUMAN ACTIONS FOR RESEARCH REACTORS

**Mita Farcasiu , Mirela Nitoi, Minodora Apostol, Gheorghe Florescu, Ilie Turcu**

***Institute for Nuclear Research Pitesti, Romania***
***farcasium@scn.ro***

## *Abstract*

To identify, evaluate and estimate the contribution of the human factor to operating of the research reactors, the Human Reliability Analysis (HRA) is used.
An important step in HRA is the dependence level analysis between the human actions, step in quantitative analysis of the human errors probabilities.
The dependence can be between two actions performed by the same person or between the actions performed by different persons (the situation in which the probability of failure (success) on one activity is different depending on whether a failure or success occurred on the other activity)
The necessary information was obtained from operating experience of research reactor TRIGA from INR Pitesti. The required data were obtained from generic databases.
This analysis is realized through the following methods:
- Standardized Plant Analysis Risk Human Reliability Analysis (SPAR-H);
- Techniques for Human Error Rate Prediction (THERP).
After realization of this analysis the conditional human error probabilities (CHEP) and joint human error probabilities (JHEP) was estimated. The achieved sensitivity analyses determine human performance sensibility at systematically variations for dependence level between human actions.
The human error probabilities estimated in this paper are adequate values for integration both in HRA and in PSA realized for TRIGA reactor. This analysis type aids to be found and analyzed the ways of reducing the likelihood of human errors, so that the impact of human factor to systems availability, reability and safety is realistically estimated

**Key words: TRIGA, human error, dependence level**

## 1. Introduction

An important step in Human Reliability Analysis (HRA) is the evaluation of the dependence between human actions and the estimation of their effect on availability and safety of nuclear installation. This theme is one of the in specific objectives of Probabilistic Safety assessment (PSA). The dependence analysis between human actions represents a phase in the quantitative analysis of Human Error Probabilities (HEPs) and is used to determine HEP in the situation in which the probability of failure (success) on one activity is different depending on whether a failure or success occurred in the other activity.

The dependence can be between the actions performed by the same person or between the actions performed by different person.

In this paper only the analysis for positive dependence level between human actions were realized. SPAR-H (Standardized Plant Analysis Risk Human Reliability Analysis) and THERP (Techniques for Human Error Rate Prediction) methods are considered to be the most adequate to be used in this situation. The necessary information was obtained from operating experience of research reactor TRIGA from INR Pitesti. The required data were obtained from generic databases.

After realization of this analysis the conditional human error probabilities (CHEP) and joint human error probabilities (JHEP) were estimated. The achieved sensitivity analyses determine human performance sensibility at systematically variations for dependence level between human actions.

The human error probabilities estimated in this paper are adequate values for integration both in HRA and in PSA realized for TRIGA reactor. This type of analysis aids to find and analyze the ways of reducing the likelihood of human errors, so that the impact of human factor to systems availability, reability and safety is realistically estimated

## 2. The positive dependence model

The positive dependence involves a positive relation between events (the success of first task increases the success probability for the next task and the failure of the firs task increases failure probability for the next task).

THERP model is a positive dependence model in which five dependence levels are evaluated as distinct points situated on continuously spectrum of the positive dependence.

- zero dependence (ZD);
- low dependence (LD);
- moderate dependence (MD);
- high dependence (HD);
- complete dependence (CD);

In figure 2-1 is presented the relative position of these five points:

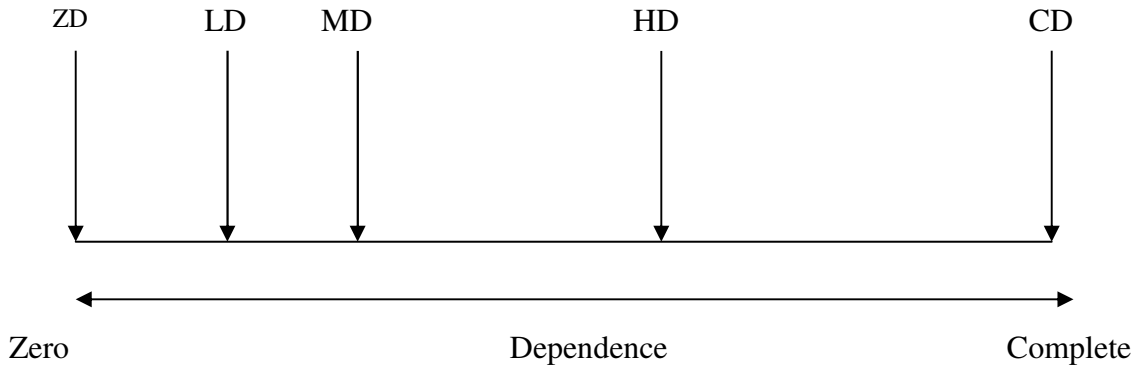



Figure 2-1 – The positive dependence represented by five distinct points

To obtain a quantitative and qualitative evaluation of the likelihood of human errors, the task analysis consisted of the following:

- the identification of the equipments which are used for the analysis of the actions.
- the identification of the failure possible actions
- the identification of the types of human error
- the identification of the situations in which was possible a failure at the realization of the action.

After the realization of the task analysis the level dependence between human actions are established.

Both SPAR-H method and THERP method present guidelines for establishment of the dependence levels.

In table 2-1 equations for quantification of the conditional human error probabilities (CHEPs) between two dependent tasks are presented.

Table 2-1 Equations for conditional probabilities of success and failure on Task "N" given success or failure on previous Task "N-1, for different levels of dependence

| **Dependence level** | **Success equations** | **Failure equations** |
|---|---|---|
| ZD | $Pr[S_{"N"}/S_{"N-1"}/ZD] = n$ | $Pr[F_{"N"}/F_{"N-1"}/ZD] = N$ |
| LD | $Pr[S_{"N"}/S_{"N-1"}/LD] = \frac{1+19n}{20}$ | $Pr[F_{"N"}/F_{"N-1"}/LD] = \frac{1+19N}{20}$ |
| MD | $Pr[S_{"N"}/S_{"N-1"}/MD] = \frac{1+6n}{7}$ | $Pr[F_{"N"}/F_{"N-1"}/MD] = \frac{1+6N}{7}$ |
| HD | $Pr[S_{"N"}/S_{"N-1"}/HD] = \frac{1+n}{2}$ | $Pr[F_{"N"}/F_{"N-1"}/HD] = \frac{1+N}{2}$ |
| CD | $Pr[S_{"N"}/S_{"N-1"}/CD] = 1.0$ | $Pr[F_{"N"}/F_{"N-1"}/CD] = 1.0$ |

For the human actions of the each activity (steps of procedures), the following types of the human error probabilities were estimated:

- basic human error probability (BHEP)
- conditional human error probability (CHEP)
- joint human error probability (JHEP)

- BHEP is estimated from generic databases
- CHEP is estimated for dependence level between two human actions
- JHEP represents a combination between BHEP and CHEP.

The representations of the human actions are realized through HRA event tree. This is the instrument of THERP method with which can be generated the quantitative estimations for the human reliability

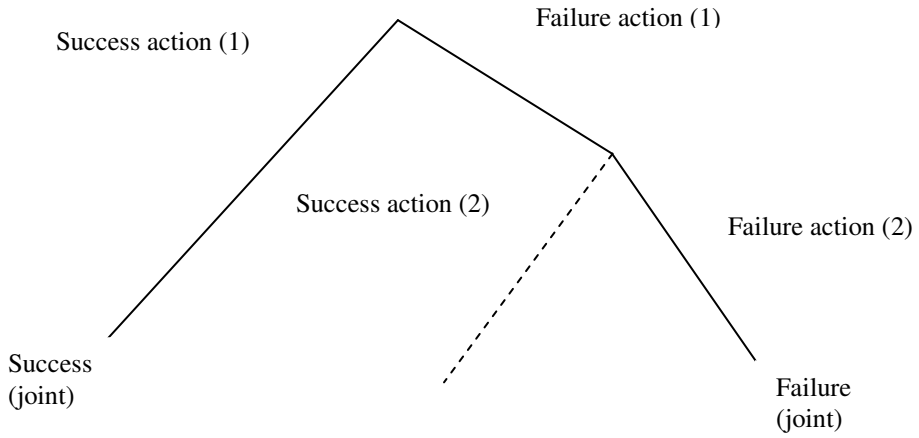



Figure 2-2 HRA event tree

For quantification JHEP of whole activity is used the following equation:

$$JHEP = \sum_{i=1}^{n} F_i \qquad (2\text{-}1)$$

## 3. Results

In order to accentuate the importance of the dependence level assessment between human actions the model presented above is applied to the operating of fuel elements in the core of TRIGA reactor.

Failure operating in the core and in the piscine of TRIGA reactor could conduce to the following events:

- mechanical damage of the core
- radiological insertion

The dependence levels in the following conditions were considered:

- all actions of the operating are realized in moderate stress level,
- the activity is realized by a team.

After the task analysis which was realized for the operating in the core, a high level dependence in the following situation was established:

- between the actions of the operators and the verification of the actions
- between the actions of the operators (a lot of oral instructions);
- between the actions of same operator (qualitative actions).

In figure 3-1 is represented a HRA event tree for the activity of the operating in the core of TRIGA reactor. For each action is specificity BHEP and CHEP when it is necessary.
In ref [] JHEP was evaluated without establishment of the dependence levels. The result is: JHEP = 0.04
If the dependence levels are evaluated then the following result is obtained:
JHEP = F1 + F2 + F3 + F4 + F5 = 0.000556 + 1.83315E-06 + 6.13575E-10 + 5.52218E-13 + 8.46951E-17 = **0.000557**
The factor of modification JHEP is f = 71.
The human reliability analysis without the consideration of the dependence levels could conduce to pessimistic results.

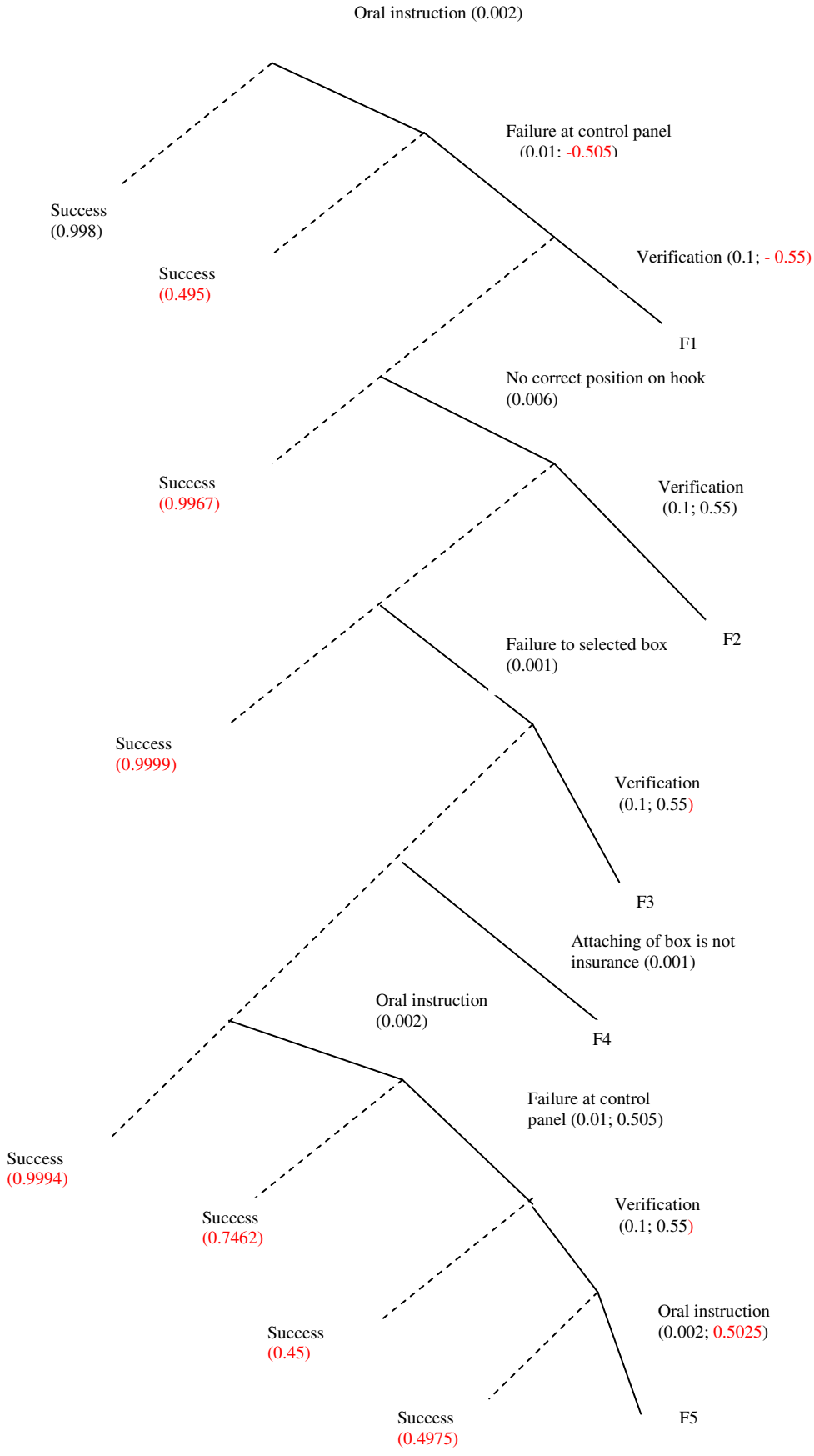
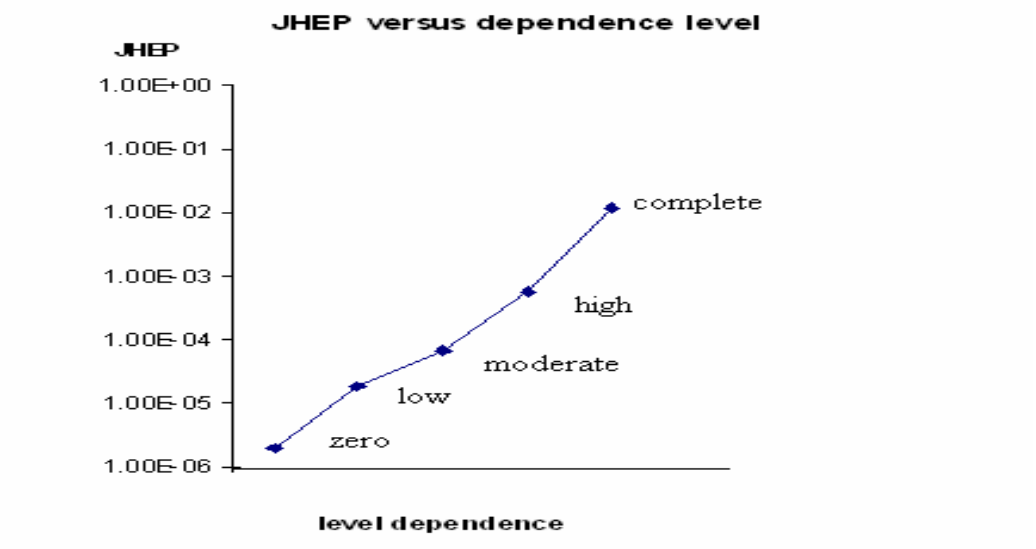



Figure 3-1 – HRA event tree of the operating of fuel elements in the core of TRIGA reactor.

In addition a sensitivity analysis is realized to present the variations JHEP to different dependence levels (figure: JHEP versus dependence level)




In table 3-1 below it is presented the evaluated variation factor of JHEP which was evaluated for all the dependence levels comparatively with JHEP which was evaluated for zero dependence level. This factor is considered to be very big for all cases.

Table3-1

| dependence level | variation factor |
|---|---|
| low | 9.02E+00 |
| moderate | 3.45E+01 |
| high | 2.77E+02 |
| complete | 5.97E+03 |

## 4. Conclusion

(I) The evaluation of the dependence level is important in realistically estimating of the contribution of the human factor in reliability and safety of the nuclear installation.

(II) In order to reduce of the HEP some recommendations can be emitted:

- the reducing of the number of manual actions;
- the modification of the dependence between human actions;
- the elimination the oral instructions;
- the all-necessary human actions must be verified.

## 5. References

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