An Interface for Enhancing Repeatability in Human Reliability Analysis

P. BARALDI\(^1\), A. SOGARO\(^2\), M. KONSTANDINIDOU\(^3\), and Z. NIVOLIANITOU\(^4\)

\(^1\)Energy Department, Politecnico di Milano, Milan, Italy
\(^2\)Department of Chemistry, Materials and Chemical Engineering, Politecnico di Milano, Milan, Italy
\(^3\)National Center for Scientific Research "DEMOKRITOS", Athens, Greece

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Abstract: In Human Reliability Analysis (HRA) methods, the estimation of Human Error Probabilities (HEPs) usually requires the assessment of the Performance Shaping Factors (PSFs) characterizing the given contextual scenario in which the tasks are performed. The objective of this work is to develop a visual interface to help the safety analysts in the PSFs assessment. Aiming at the increased repeatability of the PSFs assessment, the proposed methodology is based on the use of anchor points that represent prototype conditions of the PSFs. Furthermore, a detailed description of the anchor points in terms of sub-items characterizing the PSFs is adopted to facilitate the assessment and make the whole process more transparent. The interface is proposed with respect to a developed tool for the estimation of Human Error Probabilities (HEPs) and based on the combination of the Cognitive Reliability And Error Analysis Method (CREAM) with fuzzy logic principles.

Keywords: Visual interface, CREAM, fuzzy logic, common performance conditions, human error probabilities, human reliability Analysis, input assessment, repeatability

1. Introduction

The following acronyms have been used in this paper.

ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>ATHEANA</td>
<td>A Technique for Human Error ANAlysis</td>
</tr>
<tr>
<td>CPC</td>
<td>Common Performance Condition</td>
</tr>
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<td>CREAM</td>
<td>Cognitive Reliability and Error Analysis Method</td>
</tr>
<tr>
<td>FPE</td>
<td>Fuzzy Probability Estimator</td>
</tr>
<tr>
<td>HEP</td>
<td>Human Error Probabilities</td>
</tr>
<tr>
<td>HF</td>
<td>Human Factors</td>
</tr>
<tr>
<td>HRA</td>
<td>Human Reliability Analysis</td>
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<tr>
<td>PSA</td>
<td>Probabilistic Safety Assessment</td>
</tr>
<tr>
<td>PSF</td>
<td>Performance Shaping Factor</td>
</tr>
<tr>
<td>THERP</td>
<td>Technique for Human ERror Prediction</td>
</tr>
</tbody>
</table>

Human reliability analysis (HRA) is the part of Probabilistic Safety Assessment (PSA) that deals with human performance and its impact on risk, which in recent years has gained much attention among the PSA practitioners. Indeed, HRA is a critical element of PSA since it is the tool used to assess the implications of various aspects of human performance on risk. Although risk analysis requires an understanding of the human contri-
bution to risk, current HRA methods are limited in their ability to represent all of the important aspects of human performance. Limitations in the analysis of human actions in PSA are always recognized as a constraint in the application of PSA results. The five fundamental limitations are a) insufficient data, b) methodological limitations related to the treatment of time-scale limitations, c) omission of the possibility that operators may perform recovery actions d) subjectivity of analysts and e) uncertainty concerning the actual behavior of people during accident conditions [1-3].

Many methods have been developed in order to quantify the human performance and calculate the probability of a human erroneous action. Starting with THERP (first generation method) [4] passing from CREAM (second generation method) [5], and arriving to ATHEANA [6], all methods have tried in different ways to approach the most difficult and subjective part of PSAs – the Human Reliability Analysis.

What is common in all HRA methodologies is the assessment of the context in which the task will be or has been performed. Whether the context will be used as a corrective or a causing factor of human errors yet the assessment has to be performed at the beginning or at the end of the evaluation of Human Error Probabilities (HEPs). More specifically, in most HRA methods, the estimation of HEPs is based on the assessment of the Performance Shaping Factors (PSFs) characterizing the given contextual scenario in which the tasks and the eventual errors are performed.

In this respect, the aim of this work is to develop a visual interface for safety analysts who need to assess the PSFs characterizing the given context in which the tasks are performed. The interface should be easy to use, able to guarantee the repeatability of the assessments, even if used by different analysts and should allow for systematic tracing of the reasoning steps that lead to a given PSF assessment.

The work has been performed within VIRTHUALIS, a European Research Project on industrial safety [7]. Within the project, a specific tool based on the combination of the Cognitive Reliability and Error Analysis Method (CREAM) with fuzzy logic principles [1,5,8-9] has been developed for the estimation of Human Error Probabilities (HEPs) in industrial context. The tool, named Fuzzy Probability Estimator (FPE), requires as input from the safety analyst the assessment of the Common Performance Conditions (CPCs) characterizing the given contextual scenario in which the task is performed. The assessment should be provided in the form of numerical values representing the different aspects on appropriate scales.

The proposed interface is based on the use of anchor points that represent prototype conditions of the CPCs [10]. In order to facilitate the assessment, CPC are described in details by using specific sub-items as proposed in the taxonomy presented by Kim and Yung [11]. The allocation of the anchor points on the CPC numerical scales has been performed by interviewing four human factor experts and by appropriately aggregating their judgments.

The idea is that the comparison of the context in which the human task is performed can be evaluated against “prototype” conditions and this should increase the repeatability of the CPC assessment given that different analysts refer to the same anchor points in their analyses. Furthermore, the detailed description of the anchor points in terms of sub-items characterizing the CPCs should facilitate the CPC assessment and make the whole process more transparent.

The work is organized as follows: Section 2 presents the basic concepts of the FPE, while section 3 describes the proposed method for the definition of the anchor point, the procedural steps followed for the interface construction and the obtained final interface.
Section 4 discusses the final interface used by a safety analyst and the observations of the study and finally, the last section summarizes the conclusions of the work.

2 The Fuzzy Probability Estimator

The Fuzzy Probability Estimator (FPE) is a tool that estimates Human Error Probabilities (HEPs) for specific actions in specific contexts. The estimation is based on the CREAM methodology [5] with the use of a Fuzzy Expert System [12].

The human cognition model of CREAM assumes that the human failure probability depends directly on the level of control that the human operator has over the contextual scenario in which he/she is requested to perform the action. In the present methodology a typical failure probability interval is associated with each control mode and for a given contextual scenario, in which the task is performed, the control mode is determined by nine CPCs that qualify the context in terms of linguistic descriptors. The CPCs provide a comprehensive and well-structured basis for characterizing the conditions under which the performance is expected to take place. These CPCs are:

1) Adequacy of Organization: Defines the quality of the roles and responsibilities of team members, additional support, organization communication systems, Safety Management System, instructions and guidelines for externally oriented activities, role of external agencies; CPC levels: deficient, inefficient, efficient, very efficient.

2) Working Conditions: Describes the nature of the physical working conditions such as ambient lighting, glare on conditions screens, noise from alarms, interruptions from the task; CPC levels: incompatible, compatible, advantageous;

3) Adequacy of Man-machine Interface and Operational Support: Defines the Man-Machine Interface in general, including the information available on MMI and control panels, computerized workstations, and operational support provided by operational specifically designed decision aids; CPC levels: inappropriate, tolerable, adequate, supportive;

4) Availability of Procedures and Plans: Describes procedures and plans and includes operating and emergency procedures, familiar patterns of response heuristics, routines; CPC levels: inappropriate, acceptable, appropriate;

5) Number of Simultaneous Goals: Enumerates the number of tasks a person is required to pursue or attend to at the same time (i.e., evaluating the effects of actions, sampling new information, assessing multiple goals); CPC levels: more than actual capacity, matching current capacity, fewer than actual capacity;

6) Available Time: Pictures the time available to carry out a task and corresponds to how well the task execution is synchronized to the process dynamics. CPC levels: continuously inadequate, temporarily inadequate, adequate;

7) Time of the Day: Denotes the time of day (or night) and describes the time at which the task is carried out, in particular whether or not the person is adjusted to the current time (circadian rhythm). Typical examples are the effects of shift work. It is a well-established fact that the time of day has an effect on the quality of work, and that performance is less efficient if the normal circadian rhythm is disrupted. CPC levels: night (unadjusted), day (adjusted);

8) Adequacy of Training and Experience: Describes the level and quality of training provided to operators as familiarization to new technology, refreshing old skills, etc. It also refers to the level of operational experience; CPC levels: inadequate, adequate with limited experience, adequate with high experience;
9) **Crew Collaboration Quality**: Declares the quality of the collaboration between crewmembers, including the overlap between the official and unofficial structure, the level of trust, and the general social climate among crewmembers; CPC levels: deficient, inefficient, efficient, very efficient.

The linguistic descriptor (level) of each CPC is associated with a particular contextual effect on the performance reliability, namely whether it is improved, reduced, or not significantly modified. The number of CPCs improving and reducing performance reliability are mapped to the context-specific control mode and corresponding failure probability interval [1, 5, 8].

In order to explicitly incorporate the uncertainty and ambiguity inherent in the method, a fuzzy extension of CREAM has been proposed [1,9].

For each of the eight (from the total nine) input variables the interval that the corresponding fuzzy sets cover, lies from 0 (worst case – bad conditions) to 100 (best case – advantageous conditions). Only for the input variable “time of day” the interval of hours that the fuzzy sets cover is between 0:00 (midnight) and 24:00.

Notice that an important feature of the FPE is that it allows overlapping of the CREAM CPC levels to represent the fact that in the common perception, the transition between the linguistic concepts associated to the levels (e.g., from “efficient” to “very efficient” for the CPC “adequacy of organization”) is not crisp, but often uncertain and ambiguous. This is formally accounted for by introducing overlapping fuzzy sets to represent the CPC levels. Figure 1 reports, as an example, the partition in fuzzy sets of the CPC “adequacy of organization”.

![Figure 1: Fuzzy partition of the CPC “Adequacy of Organization”](image)

A description of the development of the fuzzy model can be found in [1, 8]. The user must supply the input values for the specific working environment or context and the system will compute the human error probability within this specific context. The results of the fuzzy model, which are in the form of crisp numbers, can be used directly in fault trees and event trees calculations for the quantification of specific undesired events that include the interaction of human factors in their modeling. The results of the model are in accordance with the results from the application of CREAM [5].

### 3 The Anchor Points Method for CPC Assessment

#### 3.1 Definition of Sub-items

The use of the FPE as well as the use of any Human Reliability Methodology requires from the safety analyst an assessment of the input parameters no matter whether they are called Performance Shaping Factors or Common Performance Conditions or Performance Influencing Factors. However, since these assessment are done on abstract and continuous scales, or by assessing linguistic characterizations to initial conditions, it is neither clear nor objective what those values mean, e.g., what does an “adequacy of organization” of 33
mean?”. The linguistic labels representing the Fuzzy Sets (e.g., “deficient”, “inefficient”, “efficient”, “very efficient”) for the CPC “adequacy of organization” proposed to the analyst by the FPE may help in this task, but they are not enough to guarantee the “repeatability” of the CPC assessment. For example a CPC judged as “deficient” for an analyst may be judged as “inefficient” by another.

Concrete guidance to the analyst in assessing the CPCs can be provided through the use of anchor points that represent prototype conditions of the CPCs appropriately allocated on their scale (Figure 2). This should facilitate the user as well as increase the repeatability of the CPC assessment task, since the anchor points give a clear meaning to the corresponding values on the CPC scales. For example all situations similar to anchor point C will be assessed with a value close to 42.

![Figure 2: Allocation Example of Anchor Points on the Scale of [0,100].](image)

The procedure followed in this work to select the anchor points and to allocate them on the CPC scales is presented in the following steps:

Step 1: A fuzzy expert establishes the scales for each CPC (for example, [0,100]) and the shape and support of the fuzzy sets representing the CPC levels.

Step 2: A list of specific sub-items that characterize each CPC in order to define the relevant anchor points is established.

Step 3: A specific procedure is followed to define concrete anchor points.

Step 4: Human Factors (HF) experts are asked to allocate the anchor points on the scales of the CPCs, i.e., to assign a numerical value to each anchor point. HF experts are required to be familiar with the basic concept of Human Reliability Analysis (HRA) and with the “classical” CREAM method.

Step 5: The allocations proposed by the different experts are aggregated in order to obtain the final position of each anchor point to be used in the interface.

In order to better illustrate the methodology, the application of the five steps of the procedure related to the CPC “adequacy of organization”, are presented below, while the results obtained by applying the same procedure to other three CPCs are reported separately in Section 3.5.

Scales and Fuzzy Sets Shape and Support: The scales and partitions in fuzzy sets of the CPC have been taken from [5] and are reported as an example with reference to the CPC “adequacy of organization” in Figure 1. The fuzzy sets that were used for the other CPCs are in accordance with the linguistic descriptors listed in Section 2.
List of Sub-items and Definition of Anchor Points: The procedure followed to associate a list of anchor points to each CPC is based on the identification of sub-items describing the CPCs. The PSF taxonomy of Kim and Jung [11] has been used to facilitate the analysts in the recognition of important parameters that should be taken into account in each CPC category (see Table 1). According to Kim and Jung, all HRA methodologies use families of the same parameters as input for their assessment. Despite different names, the items that the former include are more or less the same. The developers of the interface have chosen to follow this specific taxonomy in order to concretize the definition of the anchor points and make the whole process as transparent and objective as possible.

Table 1: Sub-items used in the Allocation of the Anchor Points for the CPCs

<table>
<thead>
<tr>
<th>CPC (CREAM)</th>
<th>Sub-items according to the Taxonomy of Kim and Jung [11]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adequacy of Organization</td>
<td>Plant specific prioritized goals/strategies</td>
</tr>
<tr>
<td></td>
<td>Attitude towards training</td>
</tr>
<tr>
<td></td>
<td>Safety/economy tradeoff</td>
</tr>
<tr>
<td></td>
<td>Routine violations</td>
</tr>
<tr>
<td>Working Conditions</td>
<td>Task location</td>
</tr>
<tr>
<td></td>
<td>Accessibility</td>
</tr>
<tr>
<td>Time of the Day</td>
<td>Day/night time</td>
</tr>
<tr>
<td></td>
<td>Shift over</td>
</tr>
<tr>
<td>Crew Collaboration</td>
<td>Clearness in role/responsibility definition</td>
</tr>
<tr>
<td>Quality</td>
<td>Direction, type, method, protocol</td>
</tr>
<tr>
<td></td>
<td>Standardization in instruction/information delivery</td>
</tr>
<tr>
<td></td>
<td>Team collaboration/cooperation</td>
</tr>
<tr>
<td></td>
<td>Adequacy of distributed workload</td>
</tr>
</tbody>
</table>

For example, for the CPC family “Adequacy of organization” four sub-items have been used. Those sub-items result from the family “Plant policy and safety culture” of the original taxonomy which according to the developers’ opinion is the closest to the meaning of “adequacy of organization” category. The recognized four sub-items are:

a) Plant specific prioritized goals/strategies, describing the presence of a functional safety management system with well-defined policies and goals as an indicator of the adequacy of organization with regard to safety in an establishment,
b) Attitude towards training implying that training should always be a top priority in the list of an efficient organization,
c) Safety/economy trade-off stressing the mentality of “safety always comes first” as a very good indicator of an efficient organization with regard to safety in an establishment, and last

d) Routine violations that reflect the mentality of personnel as well as the frequency of routine violations as an indicator of the safety management system that an organization applies in its establishment.

It should be mentioned here that other sub-items or other elements can be used for each CPC family. An analyst may choose his/her own parameters that he/she believes better describe each CPC family in various applications. The developers of the interface wanted to be as concrete as possible and to use a process that would be transparent and repeatable; for that reason a known and referenced taxonomy has been used [11].
3.2 Definition of Anchor Points

For the definition of the anchor points two different conditions may arise, namely,

a) CPCs characterized by only two sub-items, and
b) CPCs characterized by more than two sub-items.

Two limiting conditions for each sub-item (one positive and one negative) have been considered, leading to the definition of four anchor points, i.e., the four possible combinations of the sub-items conditions.

One can take the CPC “Working conditions” where only two sub-items are used: task location and accessibility. The positive situation for the first sub-item is task located in the control room and the negative one is task in field while for the accessibility part the operator might have good or bad accessibility to the specific point. Therefore the anchor points are defined in the following way:

A: Control room operation and good accessibility. In a more detailed description: the control room is characterized by good illumination, it is quiet, clean and in a very satisfactory order. Good accessibility to all the instrumentation is achievable with no obstacles in operators’ path.

B: Field operation (outside the control room) - good accessibility. Detailed description: There is no contamination from radioactive or chemical material and no necessity to wear protective clothing. There is good temperature, humidity, pressure and illumination, while the working space is large with no obstacles, demanding a small moving distance.

C: Control room operation – not satisfactory accessibility to instrumentation. This means: Bad illumination, noise, narrow work space and bad accessibility to instrumentation. There are obstacles in the control room which is not in satisfactory order and clean state.

D: Field operation and bad accessibility. Detailed description: There is physical inconvenience from protective clothing, from bad illumination and from high humidity and temperature. Vibrations and noise are high, while ventilation is not satisfactory causing some movement constriction, and demanding long moving distances in dangerous and narrow workspace with bad accessibility to components.

If a CPC is characterized by more than 2 sub-items, the latter are grouped into families formed by members with a high degree of affinity. One limiting condition is imposed on the sub-items of the family: either all sub-items of the family are positive or all are negative.

Let us use the example mentioned above for the CPC “Adequacy of Organization”. The names of the sub-items characterizing this CPC are: Plant specific prioritized goals/strategies, Attitude towards training, Safety/economy trade-off and Routine violations and they can be grouped into two families: one containing the first two sub-items and another containing the last two ones. The resulting anchor points are defined as follows:

A: Plant specific prioritized goals/strategies and safety economy trade-off. Good attitude towards training and no routine violations;
B: No Plant specific prioritized goals/strategies and no safety economy trade-off. Good attitude towards training and no routine violations;
C: Plant specific prioritized goals/strategies and safety economy trade-off. Bad attitude towards training and routine violations;
D: No Plant specific prioritized goals/strategies and no safety economy trade-off. Bad attitude towards training and routine violations.
Finally, if more than two families result from this aggregation of the sub-items, the methodology proposes a hierarchy between the families retaining only the most important families to define the anchor points.

3.3 Expert Allocation of the Anchor Points

Four Human Factor experts of the project also familiar with CREAM methodology have been asked to allocate the anchor points on the CPC scales, i.e., to assign a numerical value to each anchor point previously defined. Table 2 reports the allocation proposed by the four experts for the four anchor points A, B, C and D of the CPC “Adequacy of Organization”.

Table 2: Allocation of the Anchor Points of the CPC “Adequacy of Organization” by the four Experts and Final Allocation of the Anchor Points

<table>
<thead>
<tr>
<th>Expert</th>
<th>Expert</th>
<th>Expert</th>
<th>Expert</th>
<th>Final allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>A1</td>
<td>100</td>
<td>90</td>
<td>90</td>
<td>80</td>
</tr>
<tr>
<td>B1</td>
<td>40</td>
<td>70</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td>C1</td>
<td>20</td>
<td>30</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>D1</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>

3.4 Aggregation of the Experts’ Allocations

Since the experts usually propose different allocations for the anchor points, in order to obtain the final interface of the FPE it is necessary to aggregate their different judgments. In this framework, different techniques have been proposed for the aggregation of numerical judgments given by different experts [14, 15]. In this work, the final interface has been obtained by taking the mean of the values assigned by the experts to each anchor point. It has been verified that different aggregation techniques such as taking the median of the values proposed by the experts lead to very similar results. Table 2 reports also the final allocation of the anchor points of the CPC “Adequacy of Organization”.

It can be noticed that the final choice of allocating the anchor point B1 in correspondence of 50, the most representative value of the linguistic label “Efficient” (Table 2), seems justified since for two of the four experts the anchor point B1 characterizes only the linguistic label “Efficient”.

The final allocation as defined according to the previously described methodology for the anchor points of the CPCs “working conditions”, “Time of the day” “Crew collaboration quality” is presented in details in Tables 3, 4 and 5.
Table 3: Final Allocation of Anchor Points of the CPC “Working conditions”

<table>
<thead>
<tr>
<th>Anchor Points</th>
<th>Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2</td>
<td>Control room operation and good accessibility. Detailed description: control room characterized by a good illumination, quiet (low level of noise, no interference in the communication), clean and with a very satisfactory order. Good temperature, good accessibility to all the instrumentation, no obstacles in the control room.</td>
</tr>
<tr>
<td>B2</td>
<td>Field operation (outside the control room) - good accessibility. Detailed description: no contamination from radioactive or chemical material, no necessity to dress protective clothing, good temperature, humidity, pressure and illumination. No interference in communication with control room operators or other field operator. Low noise and vibration. Large work space, not obstacles.</td>
</tr>
<tr>
<td>C2</td>
<td>Control room operation – not satisfactory accessibility to instrumentation. Bad illumination, interference in the communication, noise, narrow work space, bad accessibility to instrumentation. Obstacles in the control room and not satisfactory order and cleanliness.</td>
</tr>
<tr>
<td>D2</td>
<td>Field operation and bad accessibility. Physical inconvenience from protective clothing, bad illumination, high humidity and temperature not comfortable. Vibrations and noise, ventilation not satisfactory, some movement constriction, long moving distances, dangerous and narrow workspace, bad accessibility to components. Obstacles and bad order and cleanliness.</td>
</tr>
</tbody>
</table>

Table 4: Final Allocation of Anchor Points of the CPC “Time of day”

<table>
<thead>
<tr>
<th>Anchor Points</th>
<th>Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A7</td>
<td>Day and low effect of the shift-over (forward rolling)</td>
</tr>
<tr>
<td>B7</td>
<td>Day and significant effect of the shift-over (backward rolling)</td>
</tr>
<tr>
<td>C7</td>
<td>Night and low effect of the shift-over (forward rolling)</td>
</tr>
<tr>
<td>D7</td>
<td>Night and significant effect of the shift-over (backward rolling)</td>
</tr>
</tbody>
</table>

Table 5: Final Allocation of Anchor Points of the CPC “Crew collaboration quality”

<table>
<thead>
<tr>
<th>Anchor Points</th>
<th>Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A9</td>
<td>Clearness in role/responsibility definition. Good team collaboration/cooperation, adequacy of distributed workload, standardization in instruction/information delivery</td>
</tr>
<tr>
<td>B9</td>
<td>Lack of clearness in role/responsibility definition. Good team collaboration/cooperation, adequacy of distributed workload, standardization in instruction/information delivery</td>
</tr>
<tr>
<td>C9</td>
<td>Clearness in role/responsibility definition. Inadequate team collaboration/cooperation and inadequate distribution workload, lack of standardization in instruction/information delivery</td>
</tr>
<tr>
<td>D9</td>
<td>Lack of clearness in role/responsibility definition. Inadequate team collaboration/cooperation and inadequate distribution workload, lack of standardization in instruction/information delivery</td>
</tr>
</tbody>
</table>

4 Safety Analyst Interaction with the Proposed Interface

The analyst who is going to use the FPE will interact only with the CPC scales and anchor points.

To better illustrate the assessment process, let us consider a case in which an analyst, using the interface shown in Figure 3 (Top), has to evaluate a situation characterized by sub-items 1 and 2 positive and sub-items 3,4,5 negative. In this case, the analyst will
choose a CPC value between the position of anchor B and C. The real position in this interval will be chosen according to his/her judgment, as shown in Figure 3 (Bottom).

![Figure 3: Top - Example of Final Interface proposed to the Analyst for the Assessment of a CPC Bottom - Analyst assessment of the CPC value.](image)

The procedure described in the previous paragraphs was followed for every CPC with relevant families and with specific anchor points defined in each case.

From a general point of view, after the completion of the process the following observations have been made:

1) None of the final allocations of the anchor points has taken the values 0 or 100. This means that the experts judge that the proposed anchor points are not the worst or best possible conditions for the CPCs.

2) The questionnaire sent to the experts implicitly suggests a ranking of the anchor points, proposing, for each CPC, as first item of the list the anchor point characterizing the best condition and as last item the worst condition. Also the ordering of the anchor points in the middle of the list implicitly suggests the opinion of the authors of the questionnaire. However, three of the four experts have proposed, for at least one of the CPC, to modify the proposed order of the anchor points. This means that the expert correctly felt free to modify the proposed ordering of the anchor points. Furthermore, it should be noticed that after the aggregation of the judgments of the four experts, the obtained positions of the anchor points agree with the proposed ordering.

3) In one case, a single anchor point has been eliminated. This has happened because the experts allocated the two intermediate points at the same scale point. Our opinion is that an interface with two anchor points representing the same numerical evaluation of the CPC can be misleading for the analyst. For this reason, one of the two anchor point was eliminated from the interface.
4) Remarkable differences. In only one case (time of the day) there was a remarkable difference between the experts’ opinion: this constituted in the evaluations of the experts regarding the effect of the shift over (forward/backward) during the day, which is small for two experts (the difference between the position of anchor point A7 and B7 is respectively 2 or 3 hours) and big for the other two (6 hours). It should be noticed that the proposed aggregation methodology results in a difference between the position of the anchor points A7 and B7 and between C7 and D7 of 4 hours.

5) Disagreement between experts. In only one case (adequacy of training) experts do not seem to agree on the importance of the most influencing factor, namely experts do not agree on which of the two factors, Good/bad training or Insufficient/good experience is influencing more the HEP. The final allocation reflects the judgments of the majority of the experts although the two anchor points result very close to each other(values of anchor points B8 and C8 are 50 and 40 respectively).

5 Conclusions

The objective of the present work has been to develop a visual interface to help the safety analysts in the PSF assessment. Aiming at the increased repeatability of the PSF assessment, the proposed interface is based on the use of anchor points that represent prototype conditions of the former. The estimation of human error probabilities either through the use of the FPE tool developed for a specific project (VIRTHUALIS) or for the purposes of human reliability analysis requires the assessment of the CPCs (or generally of the working/industrial context). In this respect, the activity object of the present work has been devoted to the development of a visual interface which facilitates the analyst in the assessment of the CPCs.

The proposed interface is based on the use of anchor points that represent prototype conditions of the CPCs. A procedure for establishing the lists of anchor points, based on the identification of sub-items to be associated to each CPC, has been proposed. The allocation of the anchor points on the CPC scales has been performed by interviewing four HF experts and by appropriately aggregating their judgments.

It should be noticed that, using the proposed interface, the comparison of the human task to be evaluated with the prototype conditions guides the analyst in the CPC assessment. Since different analysts refer to the same anchor points, the repeatability of the CPC assessment results is increased. Furthermore, the identification of sub-items describing in details the CPCs and the use of those sub-items in the description of the anchor points make the CPC assessment a more transparent process, allowing the easier tracing of its reasoning steps.

In order to test the usefulness and enhance the usability of the proposed interface, this research activity should be further developed by collecting the opinions of analysts that use the interface for their human reliability analysis. Further work should also be devoted to the verification of the repeatability of the obtained CPC assessment. In this respect, experimental tests should be conducted by asking two groups of analysts to assess the CPCs, with only one of the two groups using the proposed interface, and by analyzing the variability of the obtained assessments in the two groups.

The number and the background of experts that have been asked to allocate the prototype anchor points is also a very influencing factor on the reliability of the proposed methodology. They have to have a strong industrial experience, so as to be able to offer
classification that best describe current industrial practice. The more we can engage the better.

Finally, it should be noticed that, although this work has been focused on the assessment of the common performance conditions used by the FPE, the methodology here proposed for the development of the visual interface can be easily adapted to elucidate the performance shaping factors for other HRA methods.

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**Piero Baraldi** (B.S. in nuclear engng., Politecnico di Milano, 2002; Ph.D. in nuclear engng., Politecnico di Milano, 2006) is assistant professor at the department of Energy at the Politecnico di Milano. He is the current chairman of the European Safety and Reliability Association, ESRA, Technical Committee on Fault Diagnosis. He is functioning as Technical Programme Chair of the 2013 Prognostics and System Health Management Conference (PHM-2013). His main research efforts are currently devoted to the development of methods and techniques for system health monitoring, fault diagnosis, prognosis and maintenance optimization. He is also interested in methodologies for rationally handling the uncertainty and ambiguity in the information. He is co-author of 45 papers on international journals and 53 on proceedings of international conferences.

**Angelo Sogaro** (BS in Social Sciences, Libera Università degli Studi di Trento, 1978) is contract professor at the Department of Chemistry, Materials and Chemical Engineering at the Politecnico di Milano (Plants and Equipments in Surface Engineering). The main features of his activity have regarded mathematical modelling of chemical process, safety engineering and human reliability analysis. He is co-author of 43 papers on proceedings of international conferences and on international journals.

**Myrto Konstandinidou** (B.S. in Chemical Engineering, Double Degree from National Technical University of Athens, 2001 and Politecnico di Milano, 2000; M.Sc. in Computational Engineering, 2005, Ph.D. in Industrial Safety, 2008) is a safety engineer in the Institute of Nuclear Technology-Radiation Protection of the National Centre for Scientific Research “DEMOKRITOS”. Her research activities include quantitative risk assessment of industrial installations, occupational risk assessment and human reliability analysis. She has participated in the reviewing of SEVESO studies of the Greek industry.

**Zoe Nivolianitou** (Ph.D. in Chemical Engineering, 1989) is a research scientist in the Institute of Nuclear Technology-Radiation Protection of the National Centre for Scientific Research “DEMOKRITOS”. In the last 20 years she performs research in Safety and Risk Analysis of Chemical Plants, Safety Auditing in the process Industry and Transport of Hazardous material together with Accident and Human factors Analysis. She has worked both as a Greek expert in the reviewing of “SEVESO” studies and as an EC consultant in the evaluation and EC funded proposals.