European Clearinghouse: Organizational and management-related aspects in nuclear event analysis

Summary Report of a European Clearinghouse Topical Study

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Abstract

The research carried out within the European Clearinghouse on Operational Experience Feedback of the European Commission has paid particular attention to the further increase of the effectiveness of the Operational Experience Feedback (OEF) systems by means of improvements in methodologies for event analysis and coding. The effectiveness of the entire OEF system is strongly dependent on the quality and comprehensiveness of the coding or classification system of causal factors and root causes of events.

The research carried out at the Joint Research Centre (JRC) of the European Commission has highlighted that issues related to human, organizational and managerial factors are typically not well addressed in the event reports, which mainly focus on human errors at the individual operator or worker level. Moreover, in the existing event investigation practices, the taxonomy of human errors mostly is applied to workforce and not to management or design teams. These findings could be due to the limitations of the analysis methodologies and of the coding and classification systems of causal factors and root causes of events.

These observations have brought to concluding the importance of upgrading the coding systems used for the classification of event reports with an enhanced system ideally simple and enabling the identification and appropriate classification of human, organisational and managerial factors in the registered events.

This Summary Report presents the results of a comprehensive study performed by the European Clearinghouse on Operating Experience Feedback, which proposes a new approach for the analysis of the events and for the coding of findings, based on the adaptation of the Human Factors Analysis and Coding System (HFACS), already applied to other industries, to the investigation of Nuclear Events: HFACS-NE.

A comparative analysis of selected IRS and LERs reports has been carried out using both the IRS and HFACS-NE analysis and coding systems, proving the specific advantages of the HFACS-NE system. A conclusion of the study is that the adoption of the suggested HFACS-NE methodology of event analysis and classification could be considered in a project of upgrade or modification of the IRS coding system, which will benefit of a more detailed and comprehensive analysis and classification of the human, organizational and management-related factors.
1. Introduction

The research carried out within the European Clearinghouse on Operational Experience Feedback of the European Commission has paid particular attention to the further increase of the effectiveness of the Operational Experience Feedback (OEF) systems by means of improvements in methodologies for event analysis and coding.

A review of the last developments in this area has shown that the nuclear industry would benefit from methodologies more effective in identifying and eliminating the circumstances, precursors and causes of safety-related events due to human, organizational and managerial factors.

The nuclear industry and society benefit since long time of databases as the IAEA/NEA International Reporting System (IRS) database and the U.S. NRC database of licensees' event reports (LER), which share knowledge about occurred events. The wealth of information contained in these databases is of unequalled importance not only for the industry but for Members States and especially for the present and future generations; therefore there is an interest to exploit it at the maximum.

Every coding or classification system of causal factors and root causes of events provides to the event investigator a set of boxes where the findings of investigation should be put in. The effectiveness of the entire OEF system is strongly dependent on the quality and comprehensiveness of the coding or classification system of causal factors and root causes of events. Despite its obvious importance, human error classification has been an under-developed part of the incident investigation process, and sometimes it is based on questionable assumptions.

Accordingly, the research carried out at the Joint Research Centre (JRC) of the European Commission has highlighted that issues related to human, organizational and managerial factors are typically not well addressed in the event reports, which mainly focus on human errors at the individual operator or worker level. Moreover, in the existing event investigation practices, the taxonomy of human errors mostly is applied to workforce and not to management or design teams. These findings could be due to the limitations of the analysis methodologies and of the coding and classification systems of causal factors and root causes of events.

These observations have brought to concluding the importance of upgrading the coding systems used for the classification of event reports with an enhanced system ideally simple and enabling the identification and appropriate classification of human, organisational and managerial factors in the registered events.

The thorough analysis and practical experience gained within the JRC Topical Operational Experience Report (TOER) [1] enables to suggest some further improvements and to put forward a proposal for the classification and coding, which, if accepted, would permit a finer and more detailed classification. This classification could support the identification and finer segregation of root causes and facilitate the reporting at a higher level of detail. Besides, it is important to impact on the content of the event description itself (more information related to the organisational context of the failure is required) and on the quality of corrective actions. The improvements of the reporting will markedly enhance the effectiveness of the OEF systems and will make more efficient the sharing of lessons learnt from OEF.

In order to achieve this objective, an attempt is made in the study to introduce a new approach for the analysis of the events and for the coding of findings, followed by a trial of this approach with the event reports stored in the mentioned databases. Therefore, the Human Factors Analysis and Coding System (HFACS) [11,14], already applied to other industries, has been adapted for the investigation of Nuclear Events, proposing a HFACS-NE taxonomy, which seems to be suitable to find out not only the active failures
of the operators but also the latent conditions and causes upstream in the organization leading to those failures.

A comparative analysis of selected IRS and LERs reports has been carried out using both the IRS and HFACS-NE analysis and coding systems, proving the distinctive advantages of the HFACS-NE system, seemingly due to its capability to guide the investigator into a deeper understanding of the event, and its suitability to analyse the possible organizational and managerial factors at different hierarchical levels of the organizational structure.

Of course, the application of the HFACS-NE system to the event reports based on other conventional analysis techniques is difficult also because of the lack of information related to human factors in those reports.

The JRC Topical Operational Experience Report also reiterates the known need to move beyond technical and procedural issues to consider for example: leadership commitment, business pressures and human factors, organizational and managerial causes of problems, rather than focusing on the symptoms.

For achieving these results, together with an appropriate code and classification system, it is paramount that the investigation is carried out by an investigation team made of specialists having multidisciplinary qualifications in human factors and human performance management, and knowledgeable not only in conventional root cause analysis methods and tools but also on the HFACS-NE methodology.

A distinctive conclusion of the study is that the adoption of the suggested HFACS-NE methodology of event analysis and classification could be considered in a project of upgrade or modification of the IRS coding system, which will benefit of a more detailed and comprehensive analysis and classification of the human, organizational and management-related factors.
2. Methodology

Robust classification and recording systems allow incident investigators and analysts to organise, structure and retrieve information on errors. A human factors’ classification or coding system should be based on sound prerequisites, limiting as much as possible uncertainties and ambiguities regarding root causes of events and avoiding potential influences.

There are several different human error classifications, which are being generated to assist the analysis of human error and behaviour [2, 7, 11, 14, 20, 37]. All of them are aiming at the same objectives:

• To allow the monitoring over time of error occurrence to detect trends;
• To support the research on errors, their causes and manifestations;
• To facilitate the development of strategies to eliminate or reduce errors, or reduce their effects in systems.

The JRC Topical Operational Experience Report [1] has considered other Coding systems of root causes and causal factors, as the one used in WANO operating experience program [20, 39, 40], making comparisons with the IRS coding system [5].

Finally, it has proposed the application to the nuclear industry of the Human Factors Analysis and Classification System (HFACS).

2.1. Human Factors Analysis and Classification System for the nuclear industry

The HFACS framework is a complex linear incident and accident investigation model based on the modified Reason’s Swiss Cheese Model of accident [34], which enables users to systematically examine the human causal factors of an event. The most important advantage of the HFACS seems to be its suitability to identify and classify active and latent failures of human performance at different hierarchical layers in a systematic way. Moreover, the HFACS can guide and facilitate the accident analyst to seek out the latent conditions such as technological environment, cognitive factors, inadequate supervision and organizational climate.

The reliability of HFACS has been tested and demonstrated [11]. Originally, it was conceived for analysing and classifying operator errors in naval aviation mishaps and accidents [15, 18]. Afterwards, the model has been utilised intensively in investigating civil and military aviation accidents as well as in mining and smelting, defence, healthcare, construction, rail, utilities, oil and gas, field maintenance, marine, and entertainment [10-18].

Taking into account the positive feedback from these applications of the HFACS, the JRC Topical Operational Experience Report has considered it applicability to the nuclear industry for the analysis of events and coding of human, organizational and management-related causal factors.

The original framework of HFACS [11] includes four main levels of human factors leading to an event: 1) Unsafe Acts; 2) Preconditions for Unsafe Acts; 3) Unsafe Supervision and 4) Organizational Influence. In order to adapt HFACS to the needs of the nuclear event investigation, and to use a terminology familiar throughout the nuclear industry, some modifications were carried out, also introducing a fifth and final level considering the "Outside Factors" and including in the structure of subcategories items typical of the nuclear industry.
In this way the HFACS-NE model has been achieved, which is adapted for Nuclear Event investigation (Figure 2-1). It includes five levels with 14 causal categories, and 12 sub-categories. Both categories and sub-categories contain 104 basic human, organizational and management-related causal factors (so called “nanocodes”) representing active failures and/or latent weaknesses which create error provoking circumstances or weaken system defences.

Of course, the different levels of the model need to be considered case-by-case on the basis of the specificities of the event. The description of causal categories, sub-categories and causal factors (so called “nanocodes”) with specific examples are presented in the JRC TOER, Annex A1 [1]. The following description of the different levels of the model contains excerpts taken from [12] to which the reader may refer for additional details.

**Unsafe acts.**
This first level of HFACS-NE describes the unsafe acts of the individual that directly lead to an incident/accident. This level is typically referred to as operator error and it is where most accident investigations are focused. Unsafe acts of the operator are classified into two categories, errors and violations. In the HFACS-NE framework, errors are divided into three basic types: skill-based, decision-based, and perceptual; violations are divided in: routine and exceptional.

**Preconditions for Unsafe Acts.**
This second level of HFACS-NE describes mostly the generally latent system failures that lay dormant for long periods of time before ever contributing to an accident. Preconditions for unsafe acts include environmental factors and conditions of the individuals.

**Deficiencies in Leadership/Supervision.**
It corresponds to the third level of HFACS-NE. Inadequate actions of people in leadership/supervision positions directly influence the performance and actions of operators by creating preconditions for unsafe acts and error traps.

**Top management/Organizational Influences.**
Latent conditions within the organizational/senior management level often go unnoticed during accident investigations. These factors are difficult to find unless a clear understanding of the organization’s framework is achieved and a consistent accident investigation framework is used. Identification of causal factors at this level can also be hindered by the unwillingness to highlight the responsibilities of the company for fear of liability.

**Outside Factors.**
All organizations are required to comply with national and international safety and health standards/regulations. Additionally, an organization must answer to the community. This fifth and final level of the HFACS-NE framework is divided in regulatory factors and other factors, as legal pressures, economic pressures, pressures from environmental groups.
Figure 2-1 HFACS-NE model used for the explanation of event's evolution and for the analysis of event reports. (Blue arrows are showing the chain of causation leading to the event; red arrows are illustrating direction of causal analysis during an event investigation).
2.2. Analysis of event reports and coding of causal factors

For the purposes of this study, initial data for the analysis of human, organizational and management-related factors have been gathered from the two main sources of Operational Experience Feedback (OEF) information:

- The database of the IAEA/OECD NEA International Reporting System for Operating Experience (IRS) [5];
- The U.S. NRC database of Licensee Event Reports (LERs) [41].

The process consisted of several steps. At the very beginning of the study a set of preliminary searches on the IRS database has been performed, considering events reported during the period 2005 - 2011. Retrieving and screening incident reports from the IRS database related to the human, organizational and management related factors has not been an easy task, due to the irregularity of the terminology and the uncertainty of the definitions used by the authors of the IRS reports. After an accurate screening, a final list consisting of 144 IRS reports relevant to this study was compiled.

Due to the specific structure, format and content of the Licensee event reports contained in the NRC database the methodology adopted for the screening of the IRS reports was found not applicable for selecting the reports relevant for this study. According to [21-23, 35], practically all events somehow are related to human errors or failures of human performance. In order to confirm or deny this assumption, LERs for analysis were selected randomly without any selection criteria, taking them directly from the NRC database. In total, 112 LERs were selected for analysis from the period 2010 – 2012.

The selected event reports were analysed in depth pursuing the basic principles of the HFACS methodology. In order to identify the dominating human, organizational and management-related factors influencing the events' initiation and development, the following main assumptions were used during the analysis:

1. All events are the results of the unsafe acts of humans which are possible at any hierarchical level of operating organization as well as of organizations participating in the supply chain of equipment and services, e.g. designers, manufacturers and other contractors.
2. Unsafe acts of individuals mostly are determined by preconditions for unsafe acts, which include physical, technological and organizational environment as well as adverse personal states and limitations.
3. Preconditions for unsafe acts mostly are determined by deficiencies in leadership/supervision, i.e. by inadequate performance of first-line supervisors and managers.
4. Failures and deficiencies in leadership/supervision partially are conditioned by inadequate organizational influences coming from the senior or top management.
5. Inadequate decisions and other failures of senior management sometimes are conditioned by the adverse outside factors.

For understanding the causal factors and latent root causes stipulating the unsafe acts or their preconditions, a model for human performance for individual and for organization has been introduced. According to the model, the quality of performance is determined not only by the individual characteristics and by the physical/technical/organizational environment, but also by the individual safety/quality culture – system of values and beliefs.

Going further, a model of human performance for organization has been assumed as aggregate of individuals/groups/entities, located and functioning at the different
hierarchical levels of organizational structure, interconnected and interdependent. This model is compatible with the main principles of the HFACS-NE approach and helps to identify the cause – consequence relations during the event analysis.

In order to compare effectiveness, advantages and weaknesses of different event analysis and coding systems, each event report selected both from IRS and NRC databases was thoroughly examined using IRS and HFACS coding systems in parallel. The analysis was focused on identifying human, organizational and management related factors that might have influenced the human error resulting in the event’s occurrence.

3. Main Findings

The distribution of causal factors of events according to IRS and HFACS coding systems is completely different (see Figure 3-1). The application of the IRS taxonomy results in the division of root causes and causal factors (CF) between 3 major groups: Human performance related CF (it shares 64%), Management-related CF (16%) and Equipment-related CF (20%).

<table>
<thead>
<tr>
<th>IRS</th>
<th>HFACS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human performance related CF</td>
<td>Equipment related CF</td>
</tr>
<tr>
<td>64%</td>
<td>20%</td>
</tr>
<tr>
<td>Management related CF</td>
<td>Senior management</td>
</tr>
<tr>
<td>16%</td>
<td>20%</td>
</tr>
<tr>
<td>Equipment related CF</td>
<td>External factors</td>
</tr>
<tr>
<td>20%</td>
<td>1%</td>
</tr>
<tr>
<td>Unsafe acts</td>
<td>Preconditions</td>
</tr>
<tr>
<td>19%</td>
<td>32%</td>
</tr>
</tbody>
</table>

Figure 3-1. Results of the analysis of IRS reports: distribution of causal factors of events between major groups according to IRS and HFACS-NE coding systems.

The application of the HFACS-NE taxonomy gives a distribution of CF between different hierarchical levels of the organizational structure (see Figure 3-1). It shows that about 19% of causal factors could be attributed to unsafe acts of individuals, 32% to the preconditions of unsafe acts, 28% to deficiencies of supervision/leadership, 20% to organizational influences controlled by senior management. External factors like economic/production pressures contribute in the limited measure of about 1%.

The results of the analysis of 112 NRC licensee event reports (LERs) using both IRS and HFACS-NE analysis and coding systems are shown in Figure 3-2. The LERs were randomly chosen from the list of events which happened during years 2010 - 2013 without any pre-selection.
The application of the IRS coding system shows that the most common causal factors are those related to human performance and equipment failures, with 45% and 43% of respective occurrence, while the management related causal factors represent only the remaining 12%.

For the same events, the application of HFACS-NE results that about 26% of causal factors could be attributed to unsafe acts of individuals, 32% to the preconditions of unsafe acts, 18% to deficiencies of supervision/leadership, 23% to organizational influences controlled by senior management. Based on the information presented in the LERs, no causal factors could be attributed to the external influences.

### 3.1 Application of the IRS taxonomy for the analysis of the IRS and LERs reports

Applying the IRS taxonomy and looking deeper inside the group of human performance related CF (see Table 3-1) it appears that the most frequent root cause or causal factor in the IRS reports is “Written procedures and documents” (code 5.5.7 in IRS coding system, registered in 83 reports out of 144). In the absolute majority of IRS reports analysed this code is attributed without specifying whether the procedures were not available (code 5.5.7.1) or incomplete/inaccurate (code 5.5.7.2) or not followed (code 5.5.7.3).

Therefore, the application of the coding system results in non-detailed information. Such an uncertainty may lead to the development of corrective actions which are simple, cheap and easy to implement (usually restricted to cosmetic corrections in procedures) whose effectiveness may be not adequate.
Table 3-1: Results of the comparative analysis of the IRS and LERs reports for human performance related causal factors and root causes, made using IRS coding system.

<table>
<thead>
<tr>
<th>Order of occurrence</th>
<th>IRS Reports</th>
<th>LER Reports</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Written procedures and documents (*)</td>
<td>Procedure completeness/accuracy</td>
</tr>
<tr>
<td>2</td>
<td>Personnel work practices</td>
<td>Training/qualification</td>
</tr>
<tr>
<td>3</td>
<td>Planning /preparation of work</td>
<td>Use of Operating Experience</td>
</tr>
<tr>
<td>4</td>
<td>Training/qualification</td>
<td>Control of task/independent verification</td>
</tr>
</tbody>
</table>

(*) Note: It is not specified whether procedure was not available, incomplete/inaccurate or not followed.

The table also shows that, in order of occurrence, the other relevant CFs after "Written procedures and documents" are: "Personnel work practices", "Planning /preparation of work" and "Training/qualification". These CF are classified in the category "Human performance related CF" although they are also related to management, because, for example, activities as planning and preparation of work, control of task and independent verification could be performed by supervisors/leaders. Therefore, the intrinsic limitation of the IRS coding system does not allow the distinction between general "Human performance related" and "Management –related" factors.

Also by analysing the LERs using the IRS coding system it appears that the most frequent factor considered as root cause is "Written procedures and documents" and the most inherent issue is "Procedure completeness/accuracy" (5.5.7.2). Similarly to the IRS reports, the reasons of the low quality of the written procedures are not specified in the LERs and there is no identification of the organisational entities or processes responsible for the development and management of the procedures and other documentation. The other most recurring groups of causal factors and root-causes are "Training/qualification", "Use of Operating Experience", "Control of Task/Independent verification".

The analysis of the IRS reports shows that in the group of "Management related CF", much less populated than the group "Human performance related CF", the causal factors are, in order of relevance (see Table 3-2) : "Safety culture", "Management involvement", "Change Management", "Communication/Coordination".

The results of the LERs analysis by means of the IRS coding system gives similar casual factors, in order of relevance: Safety Culture, Management of Staff Training and Qualification, Knowledge Management and Change Management; Decision Process and Communication/ Coordination.
### Table 3-2: Comparative analysis of the IRS and LERs reports, regarding Management Related causal factors and root causes, made using IRS coding system.

<table>
<thead>
<tr>
<th>Management related CF</th>
<th>IRS Reports</th>
<th>LER Reports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order of occurrence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Safety culture</td>
<td>Safety culture</td>
</tr>
<tr>
<td>2</td>
<td>Management involvement</td>
<td>Management of staff training and qualification</td>
</tr>
<tr>
<td>3</td>
<td>Change Management</td>
<td>Knowledge management ; Change Management</td>
</tr>
<tr>
<td>4</td>
<td>Communication / Coordination</td>
<td>Communication or Coordination; Decision Process</td>
</tr>
</tbody>
</table>

Some **Equipment-related causes** usually are reported following the IRS coding system applied to IRS reports (see Table 3-3). The dominating causal factors sub-categories in this group are "Maintenance/testing/surveillance", "Design configuration/analysis" and Equipment (procurement specification, manufacture, storage and installation). It is important to note, that usually in the IRS reports only the titles and codes of subcategories are attributed, without specifying the particular causal factors from these subcategories. This specificity of IRS “Guidelines” [5, 6] does not facilitate the development of corrective actions and may prevent the easy retrieval of relevant OEF information from the event.

### Table 3-3: Comparative analysis of the IRS and LERs reports, regarding Equipment Related causal factors and root causes, made using IRS coding system.

<table>
<thead>
<tr>
<th>Equipment related CF</th>
<th>IRS Reports</th>
<th>LER Reports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order of occurrence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Maintenance, testing or surveillance</td>
<td>Maintenance, testing or surveillance</td>
</tr>
<tr>
<td>2</td>
<td>Design configuration and analysis</td>
<td>Design configuration and analysis</td>
</tr>
<tr>
<td>3</td>
<td>Equipment (procurement specification, manufacture, storage and installation)</td>
<td>Equipment (procurement specification, manufacture, storage and installation)</td>
</tr>
</tbody>
</table>
For the LERs, the dominating causal factors sub-categories in this group are the same encountered in the IRS reports.

### 3.2 Application of the HFACS-NE taxonomy for the analysis of the IRS and LERs reports

The JRC Topical Operational Experience Report [1] has shown that in the IRS reports skill-based errors and decision errors are apparently dominating the unsafe acts of individuals (1st level of the HFACS-NE framework).

Looking deeper inside this group, the most frequent type of unsafe acts is 'Procedural/checklist errors' [see Table 3-4], which are being conducted usually by well-trained individuals without significant conscious thought due to failures of attention, memory or technique. Decision-Making errors and errors due to misperception are also often encountered, followed by Errors Executing a set Action Pattern and Wilful failures to follow Procedures.

<table>
<thead>
<tr>
<th>1st level of the HFACS-NE framework</th>
<th>Order of occurrence</th>
<th>IRS Reports</th>
<th>LER Reports</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>Procedural/checklist errors</td>
<td>Procedural/checklist errors</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Decision-Making Errors</td>
<td>Error due to Misperception</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Error due to Misperception</td>
<td>Decision-Making Errors</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Error Executing a Set Action Pattern</td>
<td>Taking short-cuts</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Willful failure to follow procedures</td>
<td>Error Executing a Set Action Pattern</td>
</tr>
</tbody>
</table>

For some LERs it was sometimes difficult or even impossible to identify the most probable causal factors or root causes using the HFACS-NE taxonomy due to the insufficient information provided in the narrative.

For the unsafe acts of individuals skill-based errors and decision errors are apparently dominating. In order of occurrence Procedural/Checklist errors, Error due to Misperception, Decision-Making Errors, Taking short-cuts and Error Executing a Set Action Pattern appear. There are almost neither exceptional violations nor violations based on risk-assessment identified among unsafe acts.

**Preconditions for unsafe acts (2nd level of the HFACS-NE framework)** are those active and/or latent factors adversely affecting practices, conditions or actions of individuals and creating the so called “error traps”.

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For the LERs, the dominating causal factors sub-categories in this group are the same encountered in the IRS reports.
By analysing the IRS reports, at this level adverse preconditions related to organizational or technological environment are the most frequently observed, as well as physical/mental limitations of individuals. It is worth to note that factors of physical environment, adverse physiological state and fitness for duty are rarely considered as causal factors in the IRS reports.

Moving further to specific types of preconditions of unsafe acts, factors like failures of supervision/leadership/coordination, inadequate technical documentation, inadequate technical/procedural knowledge and inadequate equipment or tools are the most important (Table 3-5).

<table>
<thead>
<tr>
<th>2nd level of the HFACS-NE framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order of occurrence</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
</tbody>
</table>

Also in the case of the LERs, at the level of preconditions for unsafe acts, the most frequent are adverse preconditions related to organizational or technological environment as well as with physical/mental limitations of individuals. Moving further to specific types of preconditions of unsafe acts, factors like inadequate technical documentation, inadequate technical/procedural knowledge, failures of supervision/leadership/coordination and misperception of operational conditions seem to be the most important (see Table 3-5).

As said, the HFACS-NE analysis of events does not stop at identifying adverse preconditions of unsafe acts: it goes further, aiming at revealing organizational deficiencies upstairs the organizational hierarchy.

For the IRS reports, the results concerning the next (3rd) level of the HFACS-NE framework – deficiencies in leadership/supervision, indicate that the most frequently observed factor in this group is inadequate supervision (Table 3-6). The next items in this line are: failures to correct/update technical documentation, failures to provide adequate equipment, failures to introduce necessary improvements/modifications, problems in local training.
Table 3-6: Comparative analysis of the IRS and LERs reports using HFACS-NE coding system: Deficiencies in Leadership/Supervision (3rd) level of the HFACS-NE framework.

<table>
<thead>
<tr>
<th>Order of occurrence</th>
<th>IRS Reports</th>
<th>LER Reports</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Inadequate Leadership/Supervision</td>
<td>Issues in Local Training/Programs</td>
</tr>
<tr>
<td>2</td>
<td>Failure to update technical documentation</td>
<td>Inadequate Leadership/Supervision</td>
</tr>
<tr>
<td>3</td>
<td>Failure to provide adequate equipment/tools</td>
<td>Failure to provide adequate equipment/tools</td>
</tr>
<tr>
<td>4</td>
<td>Failure/delay to implement necessary improvements/modifications</td>
<td>Risk Assessment Inadequate</td>
</tr>
<tr>
<td>5</td>
<td>Risk Assessment Inadequate</td>
<td>Poor work organisation</td>
</tr>
<tr>
<td>6</td>
<td>Issues in Local Training/Programs</td>
<td></td>
</tr>
</tbody>
</table>

Whilst the IRS approach identifies poor procedures, lack of training or wrong equipment as root causes or causal factors of events, the HFACS-NE one allows finding out the latent causes of those organisational deficiencies and the responsible processes. If entities or managerial processes inadequately performing are identified, the necessary corrective actions could be targeted much more effectively.

Following the analysis of the LERs at the 3rd level of the HFACS-NE framework, the most frequently observed factor in this group is 'Issues in Local Training/Programs', 'Inadequate leadership/supervision/oversight', 'Failures to provide adequate equipment/tools', 'Risk assessment inadequate' and 'Poor work organisation'.

Like unsafe acts at the sharp end of the personnel level, some part of the Leadership/Supervision/Oversight failures may have latent roots upstairs the organizational hierarchy. Preconditions for the failures in Leadership/Supervision are often created by organizational/senior management deficiencies; for example, the wrong decisions of senior managers who are responsible for control of all processes in the organization. These represent the **(4th) level of the HFACS-NE framework**.

For the IRS reports, the most frequently observed specific types of organizational/senior management deficiencies encountered in IRS reports are (see Table 3-7): Inadequate Procedural Guidance / Documentation management; Weaknesses in programme/process management/oversight; Inappropriate organizational values/safety culture and Organisation Training Issues/Programs.
Table 3-7: Comparative analysis of the IRS and LERs reports using HFACS-NE coding system: Organizational/Senior Management Deficiencies (4th) level of the HFACS-NE framework.

<table>
<thead>
<tr>
<th>Order of occurrence</th>
<th>IRS Reports</th>
<th>LER Reports</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Process/Program Management/Oversight Inadequate</td>
<td>Organizational Training Issues/Programs</td>
</tr>
<tr>
<td>3</td>
<td>Organizational Values/Safety Culture Inadequate</td>
<td>Organizational Values/Safety Culture Inadequate</td>
</tr>
<tr>
<td>4</td>
<td>Organizational Training Issues/Programs</td>
<td>Process/Program Management/Oversight LTA Inadequate</td>
</tr>
</tbody>
</table>

For the LERs, the results of the analysis at the 4th level of HFACS-NE framework shows that deficiencies inherent to organisational processes represent the biggest share at this level. The most frequently observed specific types of organizational/senior management deficiencies in LERs are: Inadequate procedural guidance and documentation management; Programmatic errors in organization of training; Inappropriate organizational values/safety culture; Inadequate process/program Management /Oversight LTA.

Differently from the IRS methodology, the HFACS-NE approach allows the assessment of the role of Outside Factors, which constitute the 5th level of the HFACS-NE framework, in the whole process of safety degradation. Unfortunately, the external influences are rarely mentioned in the IRS reports as causal factors of some event. Only in 6 IRS reports out of the 144 analysed, outside factors such as economic/production pressure or failure of regulatory body to enforce action regarding safety risks are considered or could be assumed as causal factor of reported events.

The outside factors are not mentioned in the LERs. Like in the IRS reports the authors of LERs do not investigate the link between unsafe acts or preconditions for failure of human performance and decisions at different levels of organizational hierarchy, as senior management or, externally, at governmental level.

This could be due to the fact that event investigation teams inside the organization in many cases are not in the position to question failures either of top-management or of the outside influences. Only high-level commissions established for the investigation of catastrophic accidents and composed of independent experts are able to make objective conclusions about actual causes of accidents, including the role of top managers and outside factors [3, 4, 23, 24-28].
4. Discussion on the main findings and lessons learned

4.1 Considerations about the investigation method

The JRC Topical Operational Experience Report [1] has shown that the causes identified in the analysed IRS and LER reports reveal a considerable emphasis on physical processes, individual activities and equipment, which represent the microlevel. Much less attention is paid to organisational factors, i.e. the mesolevel, and to conditions related to regulators, associations and government, which are the macrolevel. This means that lessons will primarily be learned at the microlevel. Since failures at the microlevel in many cases are symptoms of trouble at higher levels, the investigators should have both technical and operational backgrounds for heading at a deeper understanding of the factors leading to accidents.

In fact, the use of the classification system may vary depending on the background, culture, interest, skills, knowledge and experience of the investigator [7]. The factors emphasised in the investigation reports reflect the competences and experiences of the investigators, who seem to be inclined to focus on the areas of their own expertise.

One possible way for achieving this deeper understanding is the creation of multi-modal investigation boards that provide a number of potential advantages, such as increased access to specialist competences that are shared between different sectors. Such observation seems to be valid both for the IRS and LERs event reports analysed. Moreover, because there is no commonly accepted system of definitions for the main concepts used in root cause analysis [9, 42], a considerable variance exists on what different people define as a "root cause".

These factors can give ambiguity and lack of clarity to the investigation results, which may lead to many corrective actions based on best-guesses and assumptions, with consequent hindrance to the efficient use of the resources [8, 9].

As mentioned before, an additional source of bias in the classification of human factors is the possibility for the managerial processes to influence the investigation in a particular direction and/or to limit the investigation to the identification of individual failures of shop-floor workers or junior engineering personnel. General tendency in these cases is to treat the symptoms instead of the underlying fundamental problem that is actually responsible for the occurring situation; this will produce the persistence of the issue and the need to deal later again with it [8, 9, 29, 31, 32].

An effective corrective-action program can be developed only if the root causes of an event are correctly identified. A prevailing type of lessons learned has been observed in the analysed event reports: they are formulated as needs to correct procedures, to improve training or to implement various technical modifications of the equipment. There are no lessons learned helping dealing with human, organizational and management related causal factors. Moreover, in some event reports common well-known principles or obvious needs to fulfil well-known and even mandatory technical, organisational or regulatory requirements are presented as lessons learned. Some examples of such "Lessons learned" are in the JRC TOER [1].

Trying to avoid such type of conclusions some scholars focused on the types of lessons related to human, organizational and management-related factors which could be drawn from the events and learned [33],

Pursuing this approach, a number of lessons have been revealed during the analysis of the selected IRS reports (see Table A2.3 of the JRC TOER [1]). These lessons seem to be potentially worth to be learned (or at least taken into account) and are applicable both for internal and external users.
4.2 The opportunity to improve the IRS analysis and coding system

Using the IRS analysis and coding system, the distribution of causal factors seems to be independent from the method used for the pre-selection of events to be analysed; and, even for randomly chosen LERs, it remains analogous. According to this distribution, human performance related causal factors share 45-64% and management related causal factors take 12-16% with the rest attributed to equipment.

It is difficult by means of the IRS coding system to highlight and properly classify organizational weaknesses at different hierarchical levels of organizational structure; even more difficult to point out, through the classification, the impact from external factors.

The JRC TOER study has highlighted the opportunity to improve some features of the IRS coding and classification system. The reader may find the details in the Topical Report, Section 4.3. Briefly, there is an opportunity to review the IRS coding and classification system for more consistency, for taking into account causal relationships between different factors related to Human performance, Management, and Equipment and for eliminating the overlapping between causal factors groups. It has been also observed that there are no adequate codes for attributing some frequently observed types of causal factors (e.g. design errors) listed in Table 7-1 in Annex to this summary report. For example, root cause under code 5.7.1 (design configuration and analysis) seems to be too general and not allowing to specify root causes of design errors or violations, and even to differentiate between design errors/violations made by designers and design analysis errors made by operators. Whilst it is not possible to achieve a comprehensive list of sub- and low-level factors, a revision of the coding system should consider the inclusion in the lists of sub-factors of additional relevant items.

Because Human-performance related and Management-related causal factors are not differentiated between different levels of organizational hierarchy and strictly interrelated, it is suggested to introduce in the classification and coding system elements which could ensure the analysis of the interrelations between the different levels of organizational hierarchy.

It is also suggested that the investigators of events perform a deeper analysis of organizational weaknesses and failures of human performance up to the higher levels of management system. It is important to recall that managers as well as operators, workers, technicians, engineers are humans working in different positions and suitable to make the same type of errors, or making wrong decisions or showing poor performance; therefore the same approaches should be applied to their errors or violations.

The above listed comments demonstrate that IRS coding system [5] could benefit from some improvements, and its implementation should ensure a more accurate identification of root causes and causal factors of events, especially in the area of human, organizational and management related factors.

4.3 The strengths and limitations of the HFACS-NE methodology

The HFACS-NE methodology does not focus on the unsafe acts of individuals; it facilitates digging deeper into the roots of failures of human performance, discovering the latent organisational deficiencies, the negative influences of senior managers and external factors.

HFACS-NE taxonomy could be applied to all levels of organization's management as well including top managers. Using such approach, most of the so called "organizational
deficiencies" causing major part of events can be treated and analysed in the same way as human performance errors at higher levels of organization's management.

It was observed that the application of the HFACS-NE for the analysis of event reports is usually much more time consuming. Nevertheless, the HFACS-NE framework has the capability to guide the user into a deeper understanding of the event.

For exploiting all of the HFACS-NE potential, a lot of detailed specific information is needed about the event on the spot, its actors, their conditions and other circumstances. This information should be gathered by well trained and experienced event investigators, knowledgeable both in conventional root cause analysis methods and in the HFACS-NE methodology. Only specialists having multidisciplinary qualifications in human factors and human performance management can ask right questions about mental, physiological and psychological conditions and limitations of personnel, supervisors and managers concerned in the event's evolution, as well as questions about organisational and management phenomena.

Of course, HFACS is not perfect and presents some shortcomings which have been highlighted in [30]. These include the consideration that the system has not been incorporated into a prospective analysis that may assist in classifying potentially hazardous behaviours. It is also questioned the definition and classification of error and the ability of the system to classify. Therefore, the method should be further developed for enhancing its potentialities of application.
5. Conclusions

1. The comparative analysis of the selected IRS and LER event reports, carried out in the JRC Topical Operational Experience Report by means of the IRS and HFACS-NE analysis and coding systems, has produced a number of suggestions for improvement which would benefit the IRS system, especially in identifying and classifying human, organizational and management-related factors.

2. The importance of having an effective and efficient system for the retrieval and processing of the Operational Experience Feedback (OEF) is confirmed.

3. The analysis of the IRS and LER reports shows that in several cases the root causes of events are not properly identified. For example, the most frequent findings of numerous event investigations include items such as 'lack of competence', 'inadequate procedures', 'inadequate tools or equipment'. However, there should be organizational deficiencies which have produced these misses.

4. The effectiveness of the OEF system is affected by lack of information concerning human, organizational and management-related factors; moreover, the limitations of the coding system make it difficult the retrieval of the relevant information.

5. Issues related to human and organizational factors and management deficiencies are typically not well addressed in the analysed event reports; when identified, these issues are considered as human performance errors at the individual worker level. This conclusion does not allow uncovering the organizational deficiencies.

6. This issue is partially due to the taxonomy of human errors (including slips, lapses, mistakes and violations), which is mostly applied to the workforce and not to management.

7. It is confirmed that the application of the Human Factors Analysis and Coding System (HFACS) to the nuclear events investigations (HFACS-NE) can facilitate the identification of latent failures inherent to the technological environment, cognitive factors, inadequate supervision, organizational climate and management deficiencies. It allows to better address human, organizational and management related factors.

8. The application of the HFACS-NE system to the events analysed using conventional analysis methodologies (e.g. IRS) is complicated due to the lack of information related to human factors in the event reports.

9. It is reiterated that the outcomes of the event investigation and the effectiveness of the operational experience feedback process in large extent depends on the corporate safety culture of the organization and on the individual safety/quality culture of Staff, in particular of Senior Managers.

10. The commitment to safety should by stated by oral and/or written declarations and demonstrated in practice, e.g. during the whole process of event investigation, evaluation of its results and implementation of the corrective actions.

11. It is reiterated the importance of the independence of event investigations from vested interests of any involved parties (such as line management, control authorities, certification bodies, or commercial partners).
6. Observations

1. For increasing the effectiveness of the Operational Experience Feedback system, it is necessary to improve the quality of the event’s investigation and, specifically, of the event’s report. Event investigations should be more focused on finding the latent root causes, avoiding the trap of stopping after the immediate trouble is removed or some “apparent” cause is found.

2. It is important to move beyond technical and procedural issues and focus more on leadership commitment, business pressures and the underlying safety (quality) culture of the organizations and of individuals as well as exploring human factors, organizational and management-related causes of problems rather than focusing on the symptoms.

3. The coding systems used for storage of event reports and other event-related information should be improved. The coding system should be simple and suitable to identify and classify human, organizational and management-related factors; it should include the active and latent failures of human performance at different hierarchical layers in a systematic way; it should guide and facilitate the accident analyst to seek out the latent failures/conditions, such as technological environment, cognitive factors, inadequate supervision and organizational climate or inadequate managerial decisions.

4. The improvement of the methodology of the event analysis and of the classification of findings could be achieved by means of a modification of the International Reporting System (IRS) coding system, using as background a more detailed and comprehensive analysis and classification system, for example the Human Factors Analysis and Coding System (HFACS).

5. For the successful implementation of HFACS-NE, during the event analysis and coding, the investigation team should have multidisciplinary qualifications in human factors and human performance management, and be composed of well trained and experienced event investigators knowledgeable in conventional root cause analysis methods and in the HFACS-NE methodology.

6. Finally, Safety Management should not only rely on numbers (incidents, error counts, safety threats, safety culture indicators). The absence of failure should not be taken as evidence that hazards are not present, that countermeasures already in place are effective. Error counts uphold an illusion of rationality and control, but they may offer neither real insight nor productive routes for progress on safety [19, 36, 38].
7. Annex: Taxonomy of causes of events in IRS coding system

The worldwide implementation of the unified web-based IAEA/NEA International Reporting System (IRS) had a great, positive impact on the improvement of the efficiency of the OEF related information and on maintaining high quality standards of safe operation of nuclear power plants.

The main objective of the IAEA/NEA International Reporting System for Operating Experience (IRS) is "to ensure that feedback of operating experience gained from nuclear power plants worldwide on safety related events is widely shared amongst the international nuclear community to help prevent occurrence or recurrence of serious events [4]."

The purpose of the IRS guidelines [5] is to give users the necessary background and guidance to enable them to produce IRS reports meeting a high standard of quality and effectiveness of the system, which - among others - should allow stakeholders to easily retrieve specific event information.

The IRS Guidelines and Manual [5, 6] identify and explain the following coding fields for use when preparing IRS reports:

(1) Reporting categories;
(2) Plant status prior to the event;
(3) Failed/affected systems;
(4) Failed/affected components;
(5) Cause of the event;
(6) Effects on operation;
(7) Characteristics of the event/issue;
(8) Nature of failure or error;
(9) Recovery actions.

Following the objectives of the JRC TOER report only coding category (5) "Cause of the event" has being considered. It is split into the 7 subcategories; 3 of them are intended for categorization of causal factors and root causes (see Table 7-1):

1. Human performance related (5.5);
2. Management related (5.6);
3. Equipment related (5.7).

The subcategory 5.5, "Human performance related CF", contains 11 groups of causal factors; some groups are decomposed in subgroups which, summarised are a total of 18 elementary causal factors. The subcategory 5.6 "Management related CF" contains 12 groups of causal factors; one group (5.6.1) is decomposed in a list of 4 elementary causal factors. The subcategory 5.7 "Equipment related CF" contains 4 groups of causal factors; three of them are decomposed, which produces a lists of 9 elementary causal factors. In total, 31 elementary causal factors are identified, which are root cause types.
<table>
<thead>
<tr>
<th>5.5 Human performance related</th>
<th>5.6 Management related</th>
<th>5.7 Equipment related</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5.1 Verbal communications</td>
<td>5.6.0 Other</td>
<td>5.7.0 Others</td>
</tr>
<tr>
<td>5.5.2 Personnel practices</td>
<td>5.6.1 Management direction</td>
<td>5.7.1 Design configuration and analysis</td>
</tr>
<tr>
<td>5.5.0 Others</td>
<td>5.6.1 Existence of policies, standards, expectations</td>
<td>5.7.1.1 Design analysis quality</td>
</tr>
<tr>
<td>5.5.1 Control of task/independent verification</td>
<td>5.6.1 Communication/Enforcement of policies, standards, expectations</td>
<td>5.7.1.2 Materials selection</td>
</tr>
<tr>
<td>5.5.2 Complacency/motivation/inappropriate habits</td>
<td>5.6.1.3 Production pressure/perceived pressure</td>
<td>5.7.1.3 Modifications engineering quality</td>
</tr>
<tr>
<td>5.5.3 Use of improper tools and equipment</td>
<td>5.6.1.4 Clarity of responsibility</td>
<td>5.7.1.4 Modifications engineering review process</td>
</tr>
<tr>
<td>5.5.4 Self-check practices(STAR)</td>
<td>5.6.2 Communication or co-ordination</td>
<td>5.7.2 Equipment (procurement specification, manufacture, storage and installation)</td>
</tr>
<tr>
<td>5.5.5 Questioning attitude</td>
<td>5.6.3 Management involvement, monitoring and assessment</td>
<td>5.7.2.1 Receipt inspection</td>
</tr>
<tr>
<td>5.5.6 Personnel work scheduling</td>
<td>5.6.4 Decision process</td>
<td>5.7.2.2 Parts/consumables shelf life/storage controls</td>
</tr>
<tr>
<td>5.5.7 Environmental conditions</td>
<td>5.6.5 Allocation of resources</td>
<td>5.7.2.3 Installation and commissioning</td>
</tr>
<tr>
<td>5.5.8 Man-machine interface</td>
<td>5.6.6 Change management</td>
<td>5.7.3 Maintenance, testing or surveillance</td>
</tr>
<tr>
<td>5.5.9 Alarm control &amp; maintenance practices</td>
<td>5.6.7 Safety culture</td>
<td>5.7.3.1 Foreign material exclusion controls</td>
</tr>
<tr>
<td>5.5.10 Equipment/controls labelling</td>
<td>5.6.8 Management of contingencies</td>
<td>5.7.3.2 Parts &amp; consumables selection/use</td>
</tr>
<tr>
<td>5.5.6 Training/qualification</td>
<td>5.6.9 Management of contracted work</td>
<td></td>
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<tr>
<td>5.5.7 Written procedures and documents</td>
<td>5.6.10 Management of staff training and qualification</td>
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<td>5.5.8 Procedure availability</td>
<td>5.6.11 Knowledge management</td>
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<tr>
<td>5.5.9 Procedure completeness/accuracy</td>
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<tr>
<td>Section</td>
<td>Description</td>
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<tr>
<td>5.5.7.3</td>
<td>Procedure compliance</td>
<td></td>
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<tr>
<td>5.5.8</td>
<td>Supervisory methods</td>
<td></td>
</tr>
<tr>
<td>5.5.9</td>
<td>Work organization</td>
<td></td>
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<tr>
<td>5.5.9.0</td>
<td>Others</td>
<td></td>
</tr>
<tr>
<td>5.5.9.1</td>
<td>Shift/team size or composition</td>
<td></td>
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<tr>
<td>5.5.9.2</td>
<td>Planning/preparation of work</td>
<td></td>
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<tr>
<td>5.5.10</td>
<td>Personal factors</td>
<td></td>
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<tr>
<td>5.5.10.0</td>
<td>Others</td>
<td></td>
</tr>
<tr>
<td>5.5.10.1</td>
<td>Fitness for work</td>
<td></td>
</tr>
<tr>
<td>5.5.10.2</td>
<td>Stress/perceived lack of time/boredom</td>
<td></td>
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<tr>
<td>5.5.10.3</td>
<td>Skill LTA/not familiar with job performance</td>
<td></td>
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<tr>
<td>5.5.11</td>
<td>Use of OE</td>
<td></td>
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</tbody>
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**List of abbreviations and definitions**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>CF</td>
<td>Casual Factor</td>
</tr>
<tr>
<td>HFACS</td>
<td>Human Factors Analysis and Coding System</td>
</tr>
<tr>
<td>HFACS-NE</td>
<td>Human Factors Analysis and Coding System-Nuclear Energy</td>
</tr>
<tr>
<td>HOF</td>
<td>Human and Organisational Factor</td>
</tr>
<tr>
<td>IAEA</td>
<td>International Atomic Energy Agency</td>
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<tr>
<td>IRS</td>
<td>International Reporting System</td>
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<tr>
<td>JRC</td>
<td>Joint Research Centre</td>
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<tr>
<td>LER</td>
<td>Licensee Event Report</td>
</tr>
<tr>
<td>NEA</td>
<td>Nuclear Energy Agency</td>
</tr>
<tr>
<td>OEF</td>
<td>Operating Experience Feedback</td>
</tr>
<tr>
<td>OECD/NEA</td>
<td>Organisation for Economic Cooperation and Development / Nuclear Energy Agency</td>
</tr>
<tr>
<td>TOER</td>
<td>Topical Operating Experience Report</td>
</tr>
<tr>
<td>US NRC</td>
<td>United States Nuclear Regulatory Commission</td>
</tr>
<tr>
<td>WANO</td>
<td>World Association of Nuclear Operators</td>
</tr>
</tbody>
</table>
List of figures

Figure 2-1 HFACS-NE model used for the explanation of event's evolution and for the analysis of event reports. (Blue arrows are showing the chain of causation leading to the event; red arrows are illustrating direction of causal analysis during an event investigation).

Figure 3-1 Results of the analysis of IRS reports: distribution of causal factors of events between major groups according to IRS and HFACS-NE coding systems.

Figure 3-2: Results of analysis of LER reports: distribution of causal factors of events between major groups according to IRS and HFACS-NE coding systems.
List of tables

Table 3-1: Results of the comparative analysis of the IRS and LERs reports for human performance related causal factors and root causes, made using IRS coding system.

Table 3-2: Comparative analysis of the IRS and LERs reports, regarding Management Related causal factors and root causes, made using IRS coding system.

Table 3-3: Comparative analysis of the IRS and LERs reports, regarding Equipment Related causal factors and root causes, made using IRS coding system.

Table 3-4: Comparative analysis of the IRS and LERs reports using HFACS-NE coding system: Unsafe acts of individuals (1st level of the HFACS-NE framework).

Table 3-5: Comparative analysis of the IRS and LERs reports using HFACS-NE coding system: Preconditions for unsafe acts (2nd level of the HFACS-NE framework).

Table 3-6: Comparative analysis of the IRS and LERs reports using HFACS-NE coding system: Deficiencies in Leadership/Supervision (3rd) level of the HFACS-NE framework.

Table 3-7: Comparative analysis of the IRS and LERs reports using HFACS-NE coding system: Organizational/Senior Management Deficiencies (4th) level of the HFACS-NE framework.

Table 7-1: Coding of Causal factors and root causes in IRS.
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Supporting legislation