Proceedings of the 33rd European Safety and Reliability Conference (ESREL 2023)
Edited by Mário P. Brito, Terje Aven, Piero Baraldi, Marko Čepin and Enrico Zio
 Published by Research Publishing, Singapore.
doi: 10.3850/978-981-18-8071-1_P250-cd

Development of Detailed Questions for Investigating the Status of Human and Organizational Factor (HOF) Issue Identifications from Event Investigation Processes

Jinkyun Park

Risk Assessment Research Division, Korea Atomic Energy Research Institute, Republic of Korea. E-mail: kshpjk@kaeri.re.kr

Elizabeth Solberg

Department of Human-Centred Digitalization, Institute for Energy Technology, Norway. E-mail: elizabeth.solberg@ife.no

The NEA (Nuclear Energy Agency) initiated a joint project named 'Good practices for investigators on identifying HOF issues from event analysis processes' in 2022. The overall goal of this project is to compile a catalogue of good practices that are useful for identifying HOF issues during the event investigation process. To this end, project members from 17 countries will collaborate to deliver a series of cooperative activities over four years. The objective in the first year of the project (2022) was for project members to identify a list of detailed questions that captured practices related to the identification and analysis of HOFs in event investigation processes. These questions were distributed in an electronic survey to capture the current state-of-practice in different countries. The purpose of this paper is to outline how the list of detailed questions were determined.

Keywords: Nuclear facility, Nuclear Power Plant, Human and Organizational Factor, Event Investigation, NEA.

1. Introduction

One of the most effective and direct ways to strengthen the defence-in-depth concept of nuclear facilities including nuclear power plants (NPPs) is to investigate and share learnings from the diverse incidents and accidents experienced during their operation (IAEA 2018). The identification and analysis of human and organizational factors (HOFs) in incident and accident investigations are particularly important because of their large impact on the operational safety of nuclear facilities. In this regard, in 2009, the OECD Nuclear Energy Agency (NEA) convened a workshop for subject matter experts to explore opportunities to improve the consideration of HOFs in event investigations in the nuclear industry (NEA 2011). One of the interesting results available from the proceedings of this workshop is a list of barriers to the effective consideration of HOFs in event investigations and recommendations with respect to three categories to mitigate these barriers (NEA 2011).

The risk of incidents and accidents in nuclear facilities is low and gradually declining. Indeed, the number of reports submitted to the IAEA/NEA Incident Reporting System shows a steadily decreasing trend since 2014 (NEA 2020). Still, there is evidence that when events do occur and require investigation, attention is mainly given to the identification and analysis of technical and procedural factors. One explanation for this tendency is that it is still not clear to event investigation teams how they should identify and analyse HOFs in practice (Teperi et al. 2017).

To address this issue, the NEA approved the initiation of a joint project entitled 'Good practices for investigators on identifying HOF issues from event analysis processes' in 2022 (for convenience, the term *collaborative project* will be used hereafter). The overall goal of the collaborative project is to compile a catalogue of good practices that are useful for identifying HOFs during the event investigation process. Organizations from 17 countries agreed to join the project and to support its activities over four years.

The objective in the first year of the collaborative project (2022) was for project

members to identify a list of detailed questions that captured practices related to the identification and analysis of HOFs in event investigation processes. In early 2023, these questions were distributed by the collaborative project members to regulators and licensees using an electronic survey to gather information about the current state of practice in different countries. The purpose of this paper is to outline how the list of detailed questions included in this electronic survey was determined.

2. Project Overview with Expected Timeline

Figure 1 provides an overview of the main activities to be conducted in the collaborative project over four years. As can be seen in Figure 1, the final goal of the collaborative project will be to deliver a catalogue of good practices that are useful for identifying HOF issues during the event investigation process. This catalogue is intended to be used by member organizations to help them assess and revise the processes currently used to investigate events so that they are better oriented towards addressing HOF issues.

To extract these good practices, a core activity in the collaborative project is to perform a comparative study in the second and third year (refer to the grey box in Figure 1). In this activity, volunteer organizations will reanalyse actual events using the event investigation methods and tools currently being used in their country. The pros and cons of different investigation methods and tools for identifying and analysing HOF issues will be identified and compared.

To facilitate the comparative study, it is necessary to identify the practices used in different countries to investigate events when an event is suspected to have been caused by, or was otherwise related to, HOF issues. To enable this data collection, members of the collaborative project first identified several important high-level concepts and promising questions relating to the identification and analysis of HOFs in event investigations. They then prepared a list of detailed questions for capturing information relating to these concepts. Detailed descriptions of each of the key tasks carried out by project members in this initial stage of the collaborative project are given in the following sections.

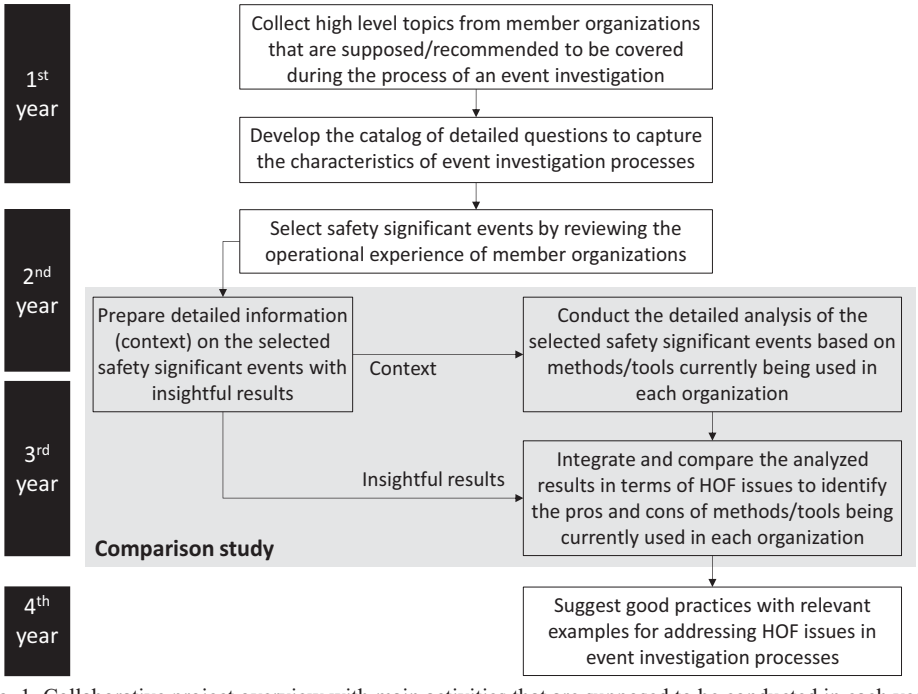

Fig. 1. Collaborative project overview with main activities that are supposed to be conducted in each year.

3. Task 1 – Identification of High-Level Topics and Promising Questions

A first task of the collaborative project members was to suggest high-level topics related to identifying and analysing HOF issues during an event investigation process and to suggest promising questions that could be used to gather information about this topic. It was assumed that different members could reflect on different topics. Accordingly, a simple template, as depicted in Table 1, was designed and circulated to project members to receive their input. This template asked members to suggest high-level topics, clarify the relevant aspects of these topics (with references), and to provide promising questions that could bring together information about this topic. As exemplified in Table 1, the high-level topic of 'Composition of event investigation team' was identified by one project member. The rationale for this concept is provided in the form of a statement taken from a specific reference and two promising questions (Q1 and Q2) were suggested.

Table 1. Template to collect high-level topics and promising questions from project members with an example.

High-level topic	**Rationale**	**Promising question**	**Reference**
Please suggest high-level topics that would be the basis for developing detailed questions.	Please clarify any sentences or paragraphs that support the high-level topics you suggested.	Please add any questions that would be necessary for clarifying the characteristics of organizations with respect to each high-level topic.	Please clarify references for rationales that you mentioned.
Composition of event investigation team	"Senior management must demonstrate support for the RCA (Root Cause Analysis) process. This includes a senior management team that is knowledgeable about the RCA process and HOF issues, supports the investigation of HOF issues, and provides the necessary resources to the team."	Q1: Is a senior manager involved in an event investigation team? Q2: Does a senior manager have knowledge about an event analysis process being used and HOF issues?	NEA (2011)

The first-round collection of high-level topics and associated promising questions was carried out with project members between February and March 2022. After the first-round collection, high-level topics that focused on similar aspects were grouped together by the project leaders. This regrouping occurred in May 2022. It was followed by a second-round review by project members to gain their consensus. As a result of this activity, a total of 35 high-level topics were identified together with 46 promising questions. Appendix A summarizes the 35 high-level topics identified.

4. Task 2 – Developing the Catalogue of Detailed Questions

A second task of the collaborative project members was to develop a catalogue of detailed questions that could be distributed in survey format to capture the current state-of-practice in different countries. In doing this, it was first necessary to assess the extent to which the high-level topics and promising questions identified in Task 1 captured, and provided sufficient coverage of, relevant characteristics of an event investigation process.

Accordingly, as a first step in Task 2, a structural model was developed to systematically organize and assess the high-level topics and promising questions identified in Task 1. The structural model developed was based on IEEE standard 1707-2015 (IEEE, 2015), which outlines recommended practices for the investigation of events at nuclear facilities. This standard identifies 27 sub-activities related to the event investigation process, categorized into seven main activities: (1) Establishing roles and responsibilities, (2) Planning, (3) Information gathering and analysis, (4) Cause determination, (5) Corrective action plan, (6) Investigation report, and (7) Records. Figure 2 depicts the overall structure of the seven main activities and sub-activities associated with each.

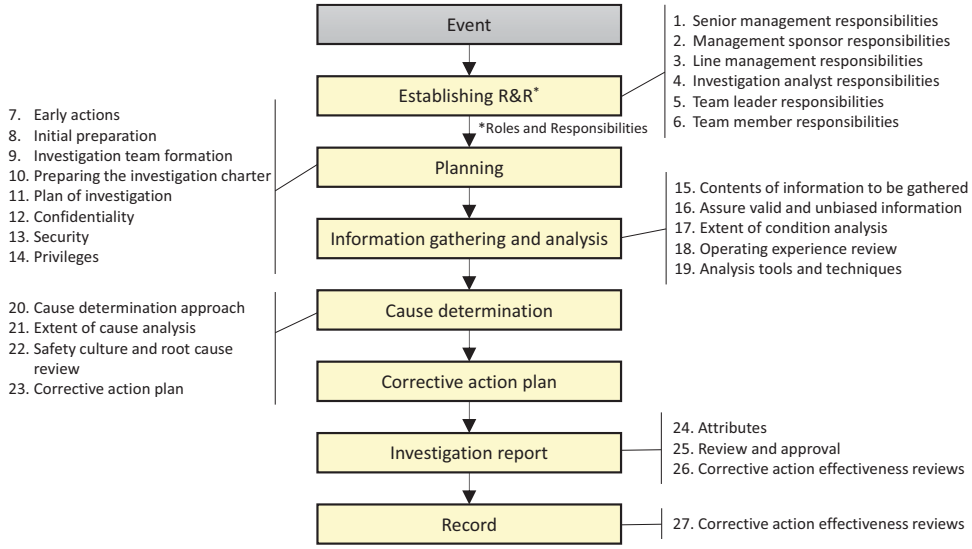

Fig. 2. Overall structure of representative activities with the associated sub-activities to be considered for the event investigation process of nuclear facilities; Reproduced from IEEE (2015).

As shown in Figure 2, the first activity to be implemented upon the initiation of an event investigation process is to establish the roles and responsibilities (R&R) of the managers and practitioners who are supposed to join the event investigation team. In this regard, it is recommended that the R&Rs of managers (e.g., senior managers, line managers), the team leader, and other team members be clearly specified. The second activity, 'Planning,' outlines a series of eight sub-activities that should be completed before the next main activity, 'Information gathering and analysis' and so on.

It was assumed that if the promising questions obtained from the high-level topics identified in Task 1 were congruent with and sufficiently covered the sub-activities illustrated in Figure 2, then they were relevant for capturing the characteristics of event investigation processes being adopted in member organizations. To facilitate this comparison, a simplified structure was proposed, as delineated in Figure 3. This simplified structure identified four main activities: 'Planning', 'Information gathering', 'Analysis', and 'Sharing and feedback.' All sub-activities identified in Figure 2 were retained and matched with the simplified activity category corresponding with their original designation in the IEEE standard.

The coverage of detailed questions proposed by the collaborative project members was analysed by comparing them with the list of 27 sub-activities shown in Figure 2. During this comparison, some promising questions suggested by project members were regrouped because their intentions seemed to resemble each other. Subsequently, the number of promising questions was reduced from 46 to 41. Table 2 summarizes the results of this comparison.

As shown in Table 2, promising questions were suggested by the collaborative project members for five of the 14 sub-activities belonging to the

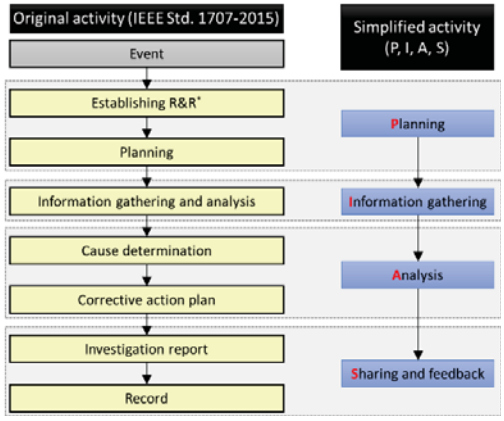

Fig. 3. Four representative activities pertaining to an event investigation process

simplified activity of 'Planning' (i.e., those corresponding to "Establishing R&R" and "Planning" in IEEE (2015)), specifically sub-activity IDs 1, 6, 9, 10 and 11. In the 'Information gathering' activity, project members offered

promising questions that corresponded to three of five sub-activities (sub-activity IDs 15, 17 and 18). In the 'Analysis' activity, project members offered promising questions that corresponded to all four sub-activities (sub-activity IDs from 20 to 23). In the 'Sharing and feedback' activity, project members offered promising questions that corresponded to three of four sub-activities (sub-activity IDs 25, 26 and 27).

Table 2. Comparison of promising questions identified with the 27 sub-activities shown in Figure 2.

Activity	ID*	Covered by promising question?
Planning	1	Yes
	2	
	3	
	4	
	5	
	6	Yes
	7	
	8	
	9	Yes
	10	Yes
	11	Yes
	12	
	13	
	14	
Information gathering	15	Yes
	16	
	17	Yes
	18	Yes
	19	
	X	Information on human errors
Analysis	20	Yes
	21	Yes
	22	Yes
	23	Yes
	X	Analysis of success cases
	X	Learning from success cases
Sharing and feedback	24	
	25	Yes
	26	Yes
	27	Yes

*ID: Sub-activity number shown in Figure 2.

Based on the overall mapping of promising questions to sub-activities, it was possible to say that the overall coverage was about 56% (i.e., 15/27). At first glance, it appeared that the coverage of promising questions was insufficient. However, it should also be mentioned that project members proposed several detailed questions that did not correspond to any sub-activities shown in Figure 2 (as indicated by an "X" in the ID column in Table 2). For example, in the case of 'Information gathering', the number of original sub-activities is five. Among those, there is no sub-activity pertaining to the collection of human-error related information. Nevertheless, in terms of addressing HOFs in event investigations, some project members pointed out that detailed questions for gathering such information was necessary. Similarly, other members suggested promising questions that could be important for addressing HOFs from different perspectives (e.g., Safety-II viewpoint instead of Safety-I). In sum, the collaborative project members indicated that event investigation activities important for addressing HOF issues could vary slightly from event investigation activities more generally.

Considering the information received in this assessment, actions were taken in developing the final catalogue of detailed questions that improved the coverage of questions in relation to sub-activities specified in Figure 2, while also ensuring coverage of topics suggested by collaborative project members that did not correspond to specified sub-activities. The final catalogue of detailed questions was developed in an iterative process, where the project leaders compiled and further developed the promising questions put forward in Task 1 in a questionnaire format. This document was shared for review and input by the collaborative project members. This work resulted in a questionnaire containing 40 questions. Appendix B provides examples of detailed questions across each activity.

5. General Conclusion

The purpose of this paper was to outline how a catalogue of detailed questions deemed useful for surveying event investigation practices that facilitate the identification and analysis of HOFs across countries was determined based on input from the collaborative project's members. As described, high-level topics and promising questions were first collected by using a dedicated template. The responses of the collaborative project members were then organized and assessed based on the recommended activities involved in conducting event investigations in nuclear facilities, as specified in existing literature. This analysis informed the further development and refinement of a final catalogue of detailed questions relevant for characterizing and comparing several practices that are important for identifying and analysing HOFs in

event investigations. In total, 40 detailed questions were specified and distributed to regulators and license holders in several countries. The results of this survey will inform the next steps of this collaborative project (see Figure 1).

Acknowledgement
Jinkyun Park's work was supported by Nuclear Safety Research Program grants from the Korea Foundation of Nuclear Safety (KOFONS), funded by the Nuclear Safety and Security Commission of the Republic of Korea (No. 2105029-0121-CG100).

Elizabeth Solberg's work was supported by the OECD Nuclear Energy Agency (NEA) Halden Human Technology Organisation (HTO) Project.

Appendix. A The 35 High-Level Topics Identified by Collaborative Project Members

- Types of Tools/Selection of Tool/Scoping
- Effectiveness of tools
- Constructing RCA (or event investigation) team
- Composition of event analysis (RCA) team
- Training of senior managers
- Training of investigators
- Training and qualification
- Independence of RCA (or event investigation) team
- Responsibilities of senior management in the event investigation process
- Timelines
- Management and organisational support
- Information gathering
- Basic information for event investigation
- Performance shaping factors
- Type of human error
- Extent of cause analysis
- Extent of condition analysis
- Event reporting system
- Screening/Selection of events
- Event analysis within contractors/suppliers
- Systematic methodology and tools
- Human error identification
- Focusing on the cause of human error
- Cause determination approach
- Inclusion of an analysis of common causes
- Depth of analysis
- Safety culture and root cause review
- Safety Culture
- Cultural aspects of events/extend of condition
- Learning from successful human behaviour observable during the progression of a failure case
- Continuous learning/transparent investigation process/regulatory oversight
- Sharing/implementing RCA (or event investigation) results
- Knowledge development and continuous learning
- Record keeping
- Self-assessment

Appendix. B Examples of Detailed Questions Developed for the Final Questionnaire

Example questions related to 'planning' activities

Please identify the people who are expected to join the event investigation team when an event is suspected to have been caused by, or was otherwise related to, HOF issues. (Mark all that apply)

a) Event investigation team leader
b) Senior manager
c) Event analysis specialist
d) HOF specialist
e) Specialist in the operation of components/systems that are necessary for explaining and/or understanding the progression of an event at hand (e.g., plant operators, subject matter experts)
f) Designers who have an expertise in components/systems that are necessary for explaining and/or understanding the progression of an event at hand
g) Reactor vendors or main suppliers who are responsible for the procurement/establishment of such components/systems as mentioned above.
h) Other (please specify):

Does each member of the event investigation team specified above have a dedicated role and responsibility (R&R)? Please provide your response for each team member involved.

Please indicate what kinds of R&Rs are assigned to the senior manager involved in the event investigation team. (Mark all that apply)

a) Participation in training on event investigation methodology and process knowledge.
b) Confirming that the members having the right knowledge and skills are assigned to the event investigation team.
c) Providing the internal and external resources required to complete the event investigation (e.g., allocating sufficient time or supporting external consultant in analyzing difficult cases).
d) Other (please specify):

Are any members of the event investigation team required to complete training or a certification program related to this work? If yes, please identify the contents of the training or certification required from the list below.

a) Investigation strategies based on the general theories of an event analysis.
b) Representative event analysis methods/tools being used in diverse industries.
c) Specific event analysis methods/tools being used in your organization.

d) General theories on HOF issues with common definitions of HOF terms.
e) Significant insights/cases pertaining to HOF issues experienced from previous event investigations or from other industries.
f) Checklists for reviewing event analysis reports for quality and consistency.
g) Other (please specify):

Are there organizational structures that support the event investigation team in conducting the event analysis without any interference (e.g., the lead investigator is not directly part of the organization or has some special rights/protections)?

Are there any guidelines/procedures to help ensure that the information gathered in the event investigation is handled ethically (i.e., that confidentiality is ensured, that sensitive findings are handled appropriately)?

Example questions related to 'information gathering' activities

What kinds of information are usually gathered during an event investigation? (Mark all that apply)
a) Information related to the event sequence (e.g., chronology of sub-events or actors' responses that are important for explaining its progression)
b) Information related to the event outcome (e.g., trip of a reactor)
c) Information related to the standards of task performance (e.g., expected sequence of actions or expected performance time to accomplish a required action)
d) Information related to actual responses (e.g., if a human operator closed a valve instead opening it as described in a procedure, it is required to collect information as to what the human operator tried to achieve and which information the human operator used to make a decision)
e) Information related to successful performance displayed during the progression of an event (e.g., any positive actions prior to or during the event sequence including those related to event mitigation or recovery)
f) Staffing-related information (e.g., the existence of a supervisor or independent checker)
g) Procedure-related information (e.g., procedures, piping and instrumentation diagrams, and other relevant documents that could indicate deficiencies or other faults with task information provided)
h) System/component related information (e.g., components being manipulated)
i) Training/education related information (e.g., expected training level for a required action or no training on a certain maintenance task)
j) HSI (Human System Interface) or HMI (Human Machine Interface) related information (e.g., complex design or wrong design)
k) Information related to physical work environment (e.g., noise, humidity, and illumination)
l) Information related to psychological work environment (e.g., uncertainties, ambiguities, and stressors)
m) Information related to teamwork aspects (e.g., workload and crew communication)
n) Information related to organizational aspects and culture (e.g., Organizational climate affected by production pressures or a lack of resources, just culture and safety culture)
o) Other (please specify):

In addition to collecting information that helps to explain how an event occurred, is information collected about similar/analogous events? If yes, what information is collected?

In addition to collecting information that helps to explain how an event occurred, is information collected about past "success cases" where similar tasks were carried out successfully or similar situations did not result in failure? If yes, what information is collected?

Are there any processes in place to verify the accuracy (or correctness) of the information gathered during the event investigation? If yes, please specify what processes are in place.

Which kinds of event analysis methods are being used? (Mark all that apply).
a) Human Performance Enhancement System (HPES)
b) Management Oversight and Risk Tree (MORT) analysis
c) Assessment of Safety Significant Event Team (ASSET)
d) Man-Technology-Organization (MTO) investigation
e) Other, please specify:

Which kinds of event analysis tools are being used? (Mark all that apply).
a) Event and Causal Factors Charting (ECFC)
b) Barrier analysis
c) Change analysis
d) Task analysis
e) Cause and effect analysis
f) Event tree analysis
g) Human factors investigation tool (HFIT)
h) Other, please specify:

Are there any specific event analysis methods/tools for identifying HOF issues that are available to the event investigation team? If yes, please specify the methods/tools available and how they support the identification of HOF issues.

The identification of human errors usually requires a set of criteria that can be used to determine whether or not the tasks, actions, and decisions conducted or taken by human operators diverged from a standard (i.e., expected behaviour). In your organization, or the organizations you are answering on behalf of, are there any criteria for identifying human errors? If yes, please indicate what the criterion are based on. (Mark all that apply).

a) Based on the consequences of the actions (e.g., actions causing irreversible system failure/malfunctioning/unavailability)
b) Based on deviations from the action as prescribed by the procedure or instruction in effect (independently of the effects of the actions on systems and components)
c) Based on deviations from training/teaching expectations for the action (e.g., deviation from action as trained/as expected from relevant documents specifying 'the conduct of operations')
d) Based on the action deviating from the intention of the actors (e.g., crew stopping depressurization at 180 psi when aiming for 150 psi due to reading the wrong pressure channel for the system, independently of the consequences of the action on the system)
e) Other (please specify):

Example questions related to 'analysis' activities

Are there any guidelines to identify the tasks, actions, and decisions conducted or taken by human operators that are important for explaining or understanding the progression of an event (e.g., in the regulatory body of the Republic of Korea, there is a dedicated guideline to identify Human Sub-Events (HSEs) that implies inappropriate human actions contributing to the occurrence of an event)? If yes, please specify what rules or guidelines are available.

In your organization or the organization(s) you are answering on behalf of, are cultural aspects (e.g., organizational culture, safety culture, national culture or something else) explicitly considered as a factor contributing to human errors? If yes, please specify how.

Are there any guidelines or processes to determine if the investigation of an event that was caused by, or was otherwise related to, HOF issues has been properly completed? If yes, please specify which guidelines or processes exist.

Example questions related to 'sharing and feedback' activities

What activities typically follow the investigation of an event? (Mark all that apply)

a) Implementation of corrective actions to reduce the recurrence of similar events
b) Publication of a report to disseminate key insights from the event investigation
c) Other (please specify):

Please specify with whom the results of an event investigation are shared.

a) With the organization (internally)
b) With reactor vendors and main suppliers
c) With the public
d) With other stakeholders (please specify):

If the results of event investigations are shared with the public, please specify what information is generally included.

a) A summary of the event investigation results.
b) Selected elements of the event investigation report (some contents of the complete event investigation report are excluded).
c) The complete report without the associated information collected during the event investigation.
d) The complete report with the associated information collected during the event investigation.

References

IAEA (2018), "Importance of sharing safety incident outcomes emphasized in panel discussion, new publication", IAEA, Vienna, iaea.org/newscenter/news/importance-of-sharing-safety-incident-outcomes-emphasized-in-panel-discussion-new-publication

IEEE (2015), *IEEE recommended practice for the investigation of events at nuclear facilities*, IEEE Std. 1707-2015, https://standards.ieee.org/ieee/1707/5449/.

NEA (2011), *Identifying and Overcoming Barriers to Effective Consideration of Human and Organisational Factors in Event Analysis and Root Cause Analysis: Workshop Proceedings* , OECD Publishing, Paris, https://www.oecd-nea.org/jcms/pl_18948.

NEA (2020), *Nuclear Power Plant Operating Experience from the IAEA/NEA Incident Reporting System*, OECD Publishing, Paris, oecd-nea.org/jcms/pl_53450/nuclear-power-plant-operating-experience-from-the-iaea/nea-incident-reporting-system-2015-2017

Teperi, A., V. Puro, and H. Ratilainen (2017), "Applying a new human factor tool in the nuclear energy industry", *Safety Science,* Vol. 95, pp. 125-139, Amsterdam, doi.org/10.1016/j.ssci.2017.02.013.