Improving Scenario Analysis for HRA

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Abstract: The International Human Reliability Analysis (HRA) Empirical Study [1, 2, 3, 4] concluded that variability in predictions of human error probabilities are in part due to deficiencies in the qualitative scenario analysis for some HRA methods. The study showed that it can be difficult for HRA analysts to gain a good understanding of how a scenario is likely to unfold, what challenges it may present to operators, how operators are likely to respond, and where performance problems may occur. Although some HRA methods include guidance on qualitative scenario analysis, most methods state only that this should precede quantification, but without specifying methods for this or the depth to which the scenario analysis should go.

A study is underway at the Halden Reactor Project in Norway to investigate scenario analysis and why it is considered difficult. The study focuses on the experience of HRA analysts in their everyday work, with the goal of understanding the challenges they face. The aim of the study is to develop a practical guidance handbook for use when performing scenario analysis. The results will include good practices implemented by analysts and further recommendations for improvement.

This paper describes the plan for this study, the findings to date and how these findings will inform a further proposed study on the development of a database to support HRA.

Keywords: HRA, Scenario Analysis, Qualitative Analysis.

1. INTRODUCTION

The International HRA Empirical study [1, 2, 3, 4] generated important insights into the strengths and weaknesses of HRA methods. The study identified variability in predictions of human error probabilities, in part due to deficiencies in the qualitative scenario analysis for some HRA methods. The study showed that it can be difficult for HRA analysts to get a good understanding of how a scenario is likely to unfold, what challenges it may present to the operators, how the operators are likely to respond, and where they may experience performance problems. Although some HRA methods include guidance on qualitative scenario analysis, other methods leave it entirely to the analyst to decide which approach to use and to which depth the scenario analysis should go.

1.1 Background

Following the International HRA Empirical Study, a US HRA Domestic Study [5] was performed which replicated the International study approach (with minor differences) to evaluate HRA methods using data from a training simulator at a US plant. During the US study [5], the HRA teams involved were asked to keep "HRA diaries" documenting their approach to the analyses they performed. These diaries were subsequently reviewed for information about the methods used by the various teams, particularly during scenario analysis. Analysis of the diaries showed significant variability between analysts with respect to resource usage (i.e., time spent on the analysis), their approaches to data collection, and the analysts' own expertise in HRA.

Semi-structured interviews were conducted in December 2012 with a small number of participants from the US study to further investigate the approach they used during the study and the challenges they encountered. In the interviews, the analysts reported a number of challenges, including a lack of clear guidance for Human Failure Event (HFE) identification and awareness or interpretation of Performance Shaping Factors (PSF)s; a lack of data to validate their analyses; uncertainties about how

to document information collected, especially where an expert judgment has been made; and understanding where improvements can be made after the quantification (e.g. in terms of ergonomics, procedures, etc.), based on the findings of the qualitative scenario analysis.

A workshop was held at the US Nuclear Regulatory Commission (NRC) in Rockville, Maryland, in December 2012, attended by HRA researchers and practitioners from a number of international organizations, to discuss the possibility of an international collaborative study on the use of simulator data to support HRA. A second workshop was held in Halden, Norway, in May 2013 to further develop this study proposal. At the second workshop it was agreed that the scenario analysis study would complement the larger international collaboration, as it proposes to investigate the process of scenario analysis itself to understand why it is difficult, how analysts use the available information, good practices for scenario analysis, and how analysts could make use of a data source such as an HRA database.

At the Halden workshop, a number of use cases for HRA were presented, one of which incorporated three activities: scenario familiarization (which includes defining the HFE scenario, scope and purpose of the analysis), qualitative data collection, and qualitative data analysis (which includes description and representation of how tasks are performed and human error identification). It was agreed at the workshop that these three activities generally encompass the scenario analysis part of an HRA. The discussion of this use case at the Halden workshop indicated that access to and availability of data is one of the most significant challenges for HRA analysts at this stage of the HRA, and that an HRA database may be useful in such instances.

Following the workshop, it was agreed that this scenario analysis study should focus on how typical HRA analysts gather data for their analysis, what kind of data they collect, the challenges associated with this, and how they could potentially use a database to support or supplement their qualitative data collection and analysis activities. Therefore the scenario analysis study will form the first phase of the international collaborative HRA data study as it will provide valuable insights regarding what kind of data analysts would like to be able to access. This in turn will enable the international collaborative study team to tailor the HRA database to include information that will be of practical use to HRA analysts.

2. STUDY OVERVIEW

2.1 Objectives of the Scenario Analysis Study

The objectives of the scenario analysis study are to explore the following questions:

- How do HRA analysts plan and conduct scenario analysis?
- What issues or aspects of the scenario do analysts typically focus on?
- What part of scenario analysis is the most challenging, and why?
- What kinds of data or information sources do analysts typically use (for example, event reports, databases, site visits, expert interviews)?
- How do analysts resolve uncertainties or contradictions during the analysis?
- How do analysts safeguard against biases or misinterpretation during the analysis?
- What good practices have analysts developed or implemented to overcome the challenges experienced?

The ultimate goal of the study is to develop a handbook for HRA analysts with practical guidance on how to perform scenario analysis. The handbook will contain advice on best practices and the aim is to write the handbook in collaboration with experienced analysts from the HRA community.

As noted earlier, the findings from this study will also be used as input to the international collaborative study on using simulator data for HRA, by providing real-world examples of the kinds of

data that analysts need, how they can use these data, and the challenges they have experienced associated with obtaining these data.

2.2 Study Plan

The study will focus on how HRA analysts perform scenario analysis in their everyday work, to gain an understanding of the real-world issues and challenges that they face. The study comprises five key steps, as shown in Figure 1 and described below. At the time of writing this paper, the first two steps have been completed.

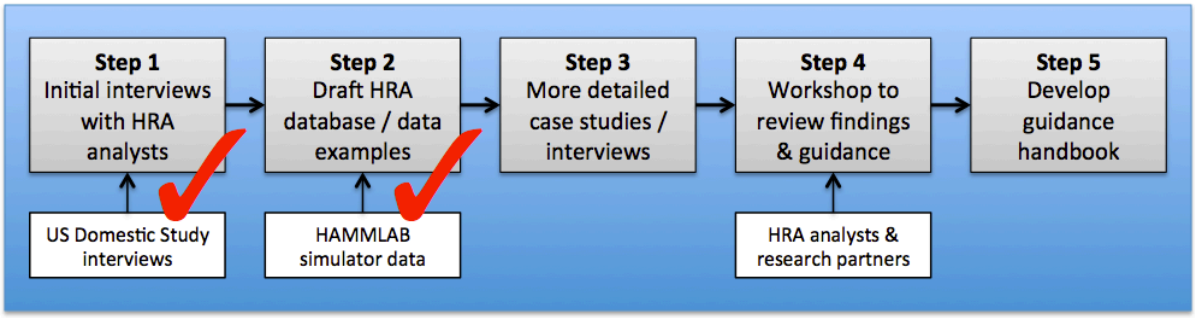


Figure 1: Scenario Analysis Study Plan

2.2.1 Step 1: Initial interviews with HRA analysts

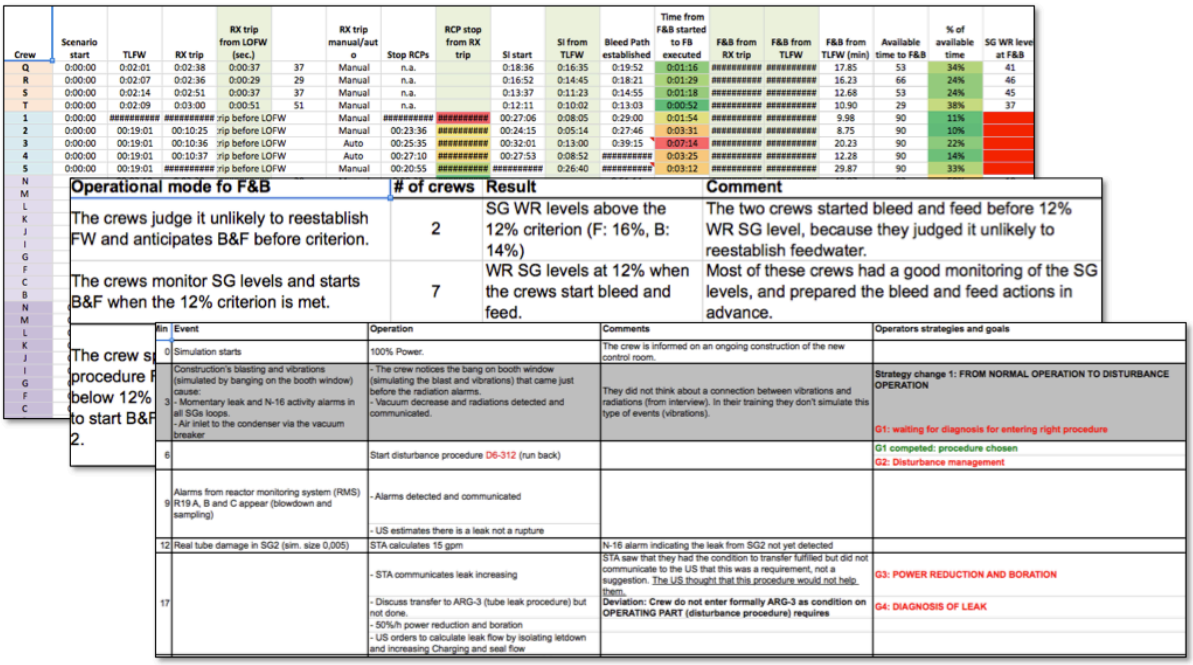
The first step in the study was to interview HRA analysts from different organizations and/or who use different HRA methods, to gain an understanding of how they usually perform scenario analyses for HRA. As noted earlier, a number of semi-structured interviews were held in December 2012 with participants from the US HRA Domestic Study. However, the interviews revealed that not all of the interviewees perform HRA as part of their "normal" everyday job. Therefore, the interviewees chosen for this scenario analysis study have been selected on the basis that they regularly perform HRA as part of their job (i.e. approximately 50% of their time is involved in HRA).

The aim of the interviews was to understand the reality of conducting a scenario analysis for HRA; what approaches do the different analysts use; what data do they seek to collect as part of the scenario analysis; what issues and challenges do they regularly face; what good practices have they developed or adopted to overcome these problems?

2.2.2 Step 2: Develop a draft HRA database and/or HRA data examples

A small sample of data collected from the Halden HAMMLAB simulator, as shown in Figure 2, has been selected. These data examples will be provided to the HRA analysts during the Step 3 case studies to test whether they consider this data to be of practical use for scenario analysis, and to explore how they could use the data. The findings here will be used as a first input to the planned international collaborative HRA data study and will also inform the development of recommendations and guidance for the scenario analysis handbook.

The data examples are taken from a Steam Generator Tube Rupture (SGTR) scenario that was simulated in the HAMMLAB. The first example includes empirical data showing timings for establishing Feed & Bleed (F&B). The second example includes qualitative data summarizing the response of the crews, and the third example includes qualitative data describing the "crew stories", which is a detailed description of how the scenario unfolded for one crew.



Crew	Scenario start	TLFW	RX trip	RX trip from LOFW (sec.)		RX trip manual/auto	Stop RCPs	RCP stop from RX trip	SI start	SI from TLFW	Bleed Path established	Time from F&B started to FB executed	F&B from RX trip	F&B from TLFW	F&B from TLFW (min)	Available time to F&B	% of available time	SG WR level at F&B
Q	0:00:00	0:02:01	0:02:38	0:00:37	37	Manual	n.a.		0:18:36	0:16:35	0:19:52	0:01:16	##########	##########	17.85	53	34%	41
R	0:00:00	0:02:07	0:02:36	0:00:29	29	Manual	n.a.		0:16:52	0:14:45	0:18:21	0:01:29	##########	##########	16.23	66	24%	46
S	0:00:00	0:02:14	0:02:51	0:00:37	37	Manual	n.a.		0:13:37	0:11:23	0:14:55	0:01:18	##########	##########	12.68	53	24%	45
T	0:00:00	0:02:09	0:03:00	0:00:51	51	Manual	n.a.		0:12:11	0:10:02	0:13:03	0:00:52	##########	##########	10.90	29	38%	37
1	0:00:00	##########	##########	rip before LOFW		Manual	##########	##########	00:27:06	0:08:05	0:29:00	0:01:54	##########	##########	9.98	90	11%	
2	0:00:00	00:19:01	00:10:25	rip before LOFW		Manual	00:23:36	##########	00:24:15	0:05:14	0:27:46	0:03:31	##########	##########	8.75	90	10%	
3	0:00:00	00:19:01	00:10:36	rip before LOFW		Auto	00:25:35	##########	00:32:01	0:13:00	0:39:15	0:07:14	##########	##########	20.23	90	22%	
4	0:00:00	00:19:01	00:10:37	rip before LOFW		Auto	00:27:10	##########	00:27:53	0:08:52	##########	0:03:25	##########	##########	12.28	90	14%	
5	0:00:00	00:19:01	##########	rip before LOFW		Manual	00:20:55	##########	##########	0:26:40	##########	0:03:12	##########	##########	29.87	90	33%	

Operational mode fo F&B	# of crews	Result	Comment
The crews judge it unlikely to reestablish FW and anticipates B&F before criterion.	2	SG WR levels above the 12% criterion (F: 16%, B: 14%)	The two crews started bleed and feed before 12% WR SG level, because they judged it unlikely to reestablish feedwater.
The crews monitor SG levels and starts B&F when the 12% criterion is met.	7	WR SG levels at 12% when the crews start bleed and feed.	Most of these crews had a good monitoring of the SG levels, and prepared the bleed and feed actions in advance.

Min	Event	Operation	Comments	Operators strategies and goals
0	Simulation starts	100% Power.	The crew is informed on an ongoing construction of the new control room.	
3	Construction's blasting and vibrations (simulated by banging on the booth window) cause: - Momentary leak and N-16 activity alarms in all SGs loops. - Air inlet to the condenser via the vacuum breaker	- The crew notices the bang on booth window (simulating the blast and vibrations) that came just before the radiation alarms. - Vacuum decrease and radiations detected and communicated.	They did not think about a connection between vibrations and radiations (from interview). In their training they don't simulate this type of events (vibrations).	Strategy change 1: FROM NORMAL OPERATION TO DISTURBANCE OPERATION G1: waiting for diagnosis for entering right procedure
6		Start disturbance procedure D6-312 (run back)		G1 competed: procedure chosen G2: Disturbance management
9	Alarms from reactor monitoring system (RMS) R19 A, B and C appear (blowdown and sampling)	- Alarms detected and communicated - US estimates there is a leak not a rupture		
12	Real tube damage in SG2 (sim. size 0,005)	STA calculates 15 gpm	N-16 alarm indicating the leak from SG2 not yet detected	
17		- STA communicates leak increasing - Discuss transfer to ARG-3 (tube leak procedure) but not done. - 50%/h power reduction and boration - US orders to calculate leak flow by isolating letdown and increasing Charging and seal flow	STA saw that they had the condition to transfer fulfilled but did not communicate to the US that this was a requirement, not a suggestion. The US thought that this procedure would not help them. Deviation: Crew do not enter formally ARG-3 as condition on OPERATING PART (disturbance procedure) requires	G3: POWER REDUCTION AND BORATION G4: DIAGNOSIS OF LEAK

Figure 2: Data examples for testing during this study

The study plan originally considered the possibility of developing a draft HRA database, but due to the interview and case study schedules, there has not been sufficient time to develop this. However, the data examples are presented in a way that mimics what an analyst could find if conducting a search in such a database. More detail on how to present and search for this data will form part of the larger international collaborative HRA data study.

2.2.3 Step 3: Case studies with HRA analysts

During the Step 1 interviews, interviewees were asked about the possibility of taking part in a more detailed case study to be carried out in 2014. The objective of the case studies would be to shadow an HRA analyst (or team of analysts) as they perform a scenario analysis for HRA during the course of their normal work. This would provide an opportunity for observation and/or discussion of how the analysts collect, sort, analyze and document data, what problems or difficulties they encounter during this process, and the approaches or good practices that they use to overcome these.

During the case studies, the analysts would also be provided with the Halden HAMMLAB simulator data (either as a sample HRA database, or individual examples of data that could be retrieved from such a database), to evaluate whether they could use this data to inform or support the scenario analysis process. Two potential detailed case studies have been identified and, at the time of writing this paper, work is underway to make arrangements for these.

2.2.4 Step 4: Workshop with analysts and research partners

Following the case studies, the findings will be analyzed and presented at a workshop, with the HRA analysts involved in the study and the research partners involved in the proposed international collaborative HRA study (depending on availability). The aim of the workshop will be to discuss the findings from the interviews and case studies, and to develop recommendations for improvements to the scenario analysis process and for the guidance handbook.

2.2.5 Step 5: Develop scenario analysis handbook

The main deliverable from this study will be a handbook of practical guidance and recommendations to improve the scenario analysis process for HRA analysts. It is intended that this handbook will assist analysts in preparing for and conducting scenario analysis, particularly for less experienced analysts.

The handbook is intended to be independent of any particular HRA method, but where good practices or recommendations specific to a particular method are identified, these will be included for those analysts who choose to use that method.

3. A TYPICAL APPROACH TO SCENARIO ANALYSIS

As noted earlier, a use case for scenario analysis was presented at the Halden workshop in May 2013. This use case described a generic approach to scenario analysis (within the context of an overall generic approach to HRA, as shown in Figure 3) and was presented to determine whether all of the workshop participants had the same understanding of the main steps in a typical scenario analysis activity. The dotted arrows in Figure 3 demonstrate that HRA is not necessarily a linear process, and that there may be several iterations between or even within individual steps.

The feedback from the workshop participants was that this diagram adequately describes the main steps in a generic HRA. The only exception was the final step – human error reduction – referring to, for example, an impact assessment of the results of the HRA to determine whether improvements should be made to reduce the likelihood of human error. It was agreed that this step is a consequence of the overall HRA and not actually a part of the generic HRA process. However, as this part of the approach to HRA is outside the scope of this project, this issue is not discussed further here.

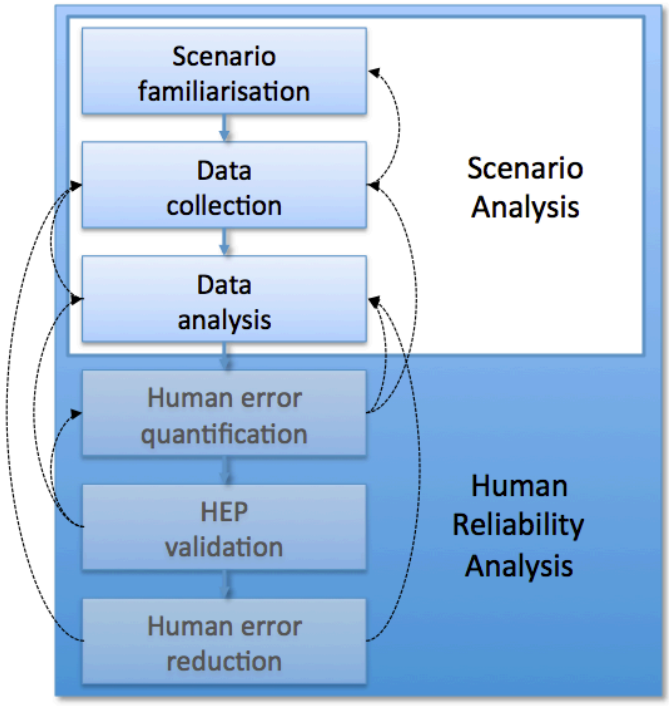


Figure 3: A typical approach to HRA and Scenario Analysis

Therefore, the steps in a typical scenario analysis are generally agreed to be as follows:

- **Scenario familiarization:** This step involves the preparation for the HRA, when the analyst explores and defines the scenario, scope and purpose of the HRA. The analyst will usually gather basic information about the scenario in order to prepare for the more formal data

collection step. This can often include discussions with Probabilistic Risk Assessment (PRA) analysts and/or other subject matter experts, and a documentation review (e.g. scenario description, event reports, operator stories, operating procedures, system descriptions, plant drawings, shift logs, etc.).

- **Data collection:** This step involves a more formal process for collecting information about the HRA scenario. The information collected will usually be qualitative, but may also include quantitative data, for example, from a training simulator. The data collection step may include a walk-through or talk-through of the scenario with subject matter experts in the training simulator or on the plant, task observations, interviews with operators, process engineers, trainers or other relevant personnel and/or review of local event reports and additional plant documentation, such as checklists, job aids, etc.
- **Data analysis:** This step usually involves the description and representation (for example, in a hierarchical and/or tabular task analysis structure) of how tasks are performed for the scenario of interest. This will be based on the qualitative and quantitative information gathered during the data collection step, and will often include some human error identification. This step provides an opportunity to check for knowledge gaps in the information gathered about the scenario. The step may include some task and error analysis.

The above description of a generic approach to scenario analysis was used as to set the scene for the interviews carried out for this scenario analysis project; i.e. that scenario analysis tends to take place before quantification and tends to include primarily qualitative data collection and analysis activities.

4. FINDINGS TO DATE

4.1 Interviews with Participants in US HRA Domestic Study

4.1.1 Overview of the Domestic Study

The 2010 US HRA Domestic Study [5] was a follow-on study from the International HRA Empirical Study [1, 2, 3, 4], primarily to test the consistency and accuracy of HRA predictions amongst different analyst teams using the same HRA methods. A key difference between the International and the Domestic studies is that for the International study, the HRA teams did not have an opportunity to visit the "plant" (in this case, the HAMMLAB simulator in Halden) to observe and collect data about the scenarios under analysis; instead, data from the HAMMLAB simulator were provided to them. However, for the domestic study, the HRA teams were able to visit the plant site to observe a training scenario, take notes, review simulator logs, audio and video recordings and debriefing interviews.

The HRA teams in the domestic study also had the opportunity to interview the simulator instructors about the scenarios being analyzed and other relevant aspects, such as use of procedures, expected operator actions, etc. Therefore, the domestic study methodology more closely resembled a real-life approach to qualitative data collection for HRA. For this reason, it was considered relevant to this scenario analysis study to interview some of the participants in the domestic study to explore their experiences with aspects of the HRA such as: identification of Human Failure Events (HFEs); data collection to inform and support the analysis; challenges and limitations associated with the HRA methods used, and their "wish list" for improvements to HRA and HRA methods for future analyses.

4.1.2 Findings from Interviews

Nine participants of the domestic study were interviewed in total. The interviewees had varying levels of HRA knowledge and experience, ranging from very experienced persons who perform HRA as part of their daily work and/or have been involved in the development of HRA methods, through to persons who had no experience of HRA prior to the domestic study, and who do not perform HRA as part of their daily work. We considered it useful to interview both the experienced HRA analysts to learn from their insights into real-world analyses, and also to interview the non-experienced study

participants as their insights from the domestic study would be similar to those of analysts who are new to HRA.

Scenario Familiarization

The scenario and the HFEs for analysis are usually defined by the PRA, although the definitions can sometimes be at a high level, in which case the HRA analyst will need to investigate and describe these in more detail. In other cases, the HRA analyst may be provided with a scenario description only, and will have to identify the operator actions and HFEs themselves. The definition and/or scope of the scenario and the HFEs can often change over the course of the analysis as more information about these are collected and analyzed. It is important to revisit these definitions throughout the analysis to ensure they are sufficiently described.

Data Collection

Analysts will almost always review operating procedures in the first instance, to gain an understanding of the HFEs and operation actions for the scenario being analyzed. Some interviewees stated that they will also usually discuss the scenario and HFEs with a PRA analyst to ensure they have a good understanding of the initiating events and sequence timings, etc.

All of the interviewees considered that a visit to the plant and/or the training simulator is the best way to collect information about the scenario and the HFEs. Here the analyst can get an impression of how quickly the scenario could unfold, how many and what kinds of cues and alarms the operator would expect to receive, whether there could be conflicting or simultaneous communications from multiple sources, and the impact of factors such as these on operator performance.

The interviewees with experience of visiting training simulators noted that it may not always be possible to observe the actual scenario being analyzed, however it is always useful to observe whatever scenarios are being run in the simulator at the time of the analyst's visit. Two of the more experienced interviewees stated that the purpose of observing simulator runs is not to collect empirical or statistical data about that scenario, but rather to collect qualitative information about how operating crews work; i.e. how they use procedures, how they communicate with each other, how they respond to alarms, how they work together as a team, how they interface with the system and equipment, the impacts of PSFs on their performance, etc.

Most of the analysts interviewed stated that it is important to fully understand the scenario and the HFEs before visiting the plant or training simulator to perform observations and talk with plant personnel. The analyst should first study available documentation such as system descriptions, operating procedures, training documents, event reports, and previous analyses (if these exist) etc. to familiarize and inform themselves on all aspects of the scenario. One of the interviewees noted that it is often useful to talk to the PRA team at the plant, as they will often have a better understanding of the purpose of the HRA and can help to ensure that the HRA analyst understands how the scenario fits into the overall PRA model and the factors that are likely to affect the scenario.

Data Analysis

One of the interviewees stated that most of the data analysis is done prior to visiting the plant or simulator, based on the information collected beforehand, e.g. from reviewing operating procedures and other relevant documentation, discussion with PRA analysts, previous knowledge of the plant, etc. The analyst will then review the analysis with a PRA team prior to visiting the plant or simulator, and uses the plant visit as a means of checking and confirming the data analysis. However, this approach does not appear to be typical for the other analysts interviewed, most of whom stated that they would perform some high-level analysis prior to the plant visit to inform their data collection. The majority of their analysis would be performed after the visit, when they have gathered the required data.

Main Challenges

There were two key challenges (relevant to this scenario analysis study) that were reported by some of the interviewees. For the less experienced analysts, a significant challenge is the lack of guidance on how to develop an overall understanding of the scenario, how to prepare for a site visit and interviews with plant personnel, and how to collect and interpret qualitative data. It can be difficult even for experienced analysts to correctly identify and interpret PSFs.

Another challenge is that simulator observations may not always reflect the reality of the scenario; for example, in the simulator, operators may skip or run quickly through certain steps in a procedure to quickly get to the relevant instructions, whereas in reality they would take their time and work systematically through all of the procedural steps.

4.2 Interviews with HRA Analysts for Scenario Analysis Study

At the time of writing this paper, seven semi-structured interviews have been held with individuals working in HRA (i.e. who perform HRA for at least part of their job). The interviewees come from a range of different organizations, including a nuclear regulatory organization, a power plant operating organization and a number of different consulting organizations. The interviewees also have different experiences in terms of the HRA methods that they currently use (or have used in the past) and the context within which these methods are applied for HRA.

Planning And Conducting Scenario Analysis

Most of the analysts interviewed use a similar approach for planning and conducting the scenario analysis. To familiarize themselves with the scenario and HFE(s), some analysts reported that they will contact the plant in advance to request information relevant to the scenario – this may include system descriptions, operating procedures, event reports, and information about the how the scenario is likely to unfold etc. Many analysts stated that they would usually spend some time discussing the scenario and HFE(s) with a PRA analyst to ensure they understand the context of the scenario and the operator actions that are likely to occur.

Some analysts noted that they will review previous analyses of the same or similar scenarios (if these are available), in some cases because the HRA they are currently engaged in may be an update to a previous analysis, and in other cases because the previous analyses can provide useful information about the scenario, the types of issues that may influence the scenario and about what was done previously to analyze these.

All of the analysts reported that they will visit the plant and/or simulator, but opinions varied regarding which site is more useful for data collection. In some cases, the interviewees stated that it is almost impossible to realistically reproduce the scenario at the plant (due to the fact that it is an operating plant) and so the information obtained does not reflect how a scenario would actually unfold. Rather, simulator observations were considered by these interviewees to be more useful as the scenario can be more realistically reproduced and so the analyst obtains a more accurate representation of how operators would react in that scenario.

However, almost all of the analysts reported that it can be difficult to observe the exact scenario being analyzed, and often the analyst has to make do with observation of similar scenarios or even with whatever scenario is being simulated at the time of the visit. In this case, the analyst can obtain more general information about team working, communication, use of procedures etc., rather than information specific to the analysis. A small number of interviewees noted that, as external contractors, it can be more difficult to get access to the simulator and so they cannot guarantee that they will be able to observe any simulations. Regardless, all of the interviewees stressed the importance of talking to operators (and simulator trainers, where possible) in addition to performing observations, to verbally talk through and get their opinions on the scenario.

Types of Data or Information Obtained During Scenario Analysis

All interviewees reported similar types of information or data that they seek during scenario analysis, which includes:

- The timeline and sequence of events – this was quoted by most analysts as being the most important aspect of the HRA;
- The role of the operator during the scenario – what actions the operator is expected to perform;
- Which procedures operators use, and how they use the procedures;
- Which alarms and cues operators receive, how they respond to these, and the time available and time taken for response;
- Which decisions the operators will have to make, and how they make these decisions;
- General information about how the operating team works together, and how they communicate during the scenario.

Some of the analysts noted that it may not always be possible to obtain all of the above information; sometimes the analyst must "take whatever they can get". But almost all of the interviewees specified that it is essential to get the operators' opinions on the scenario – how easy or difficult the scenario would be and whether what they are expected to do would be obvious to them (and how) – again stressing the importance of talking to the operators as part of the scenario analysis.

Key Challenges Associated with Scenario Analysis

Getting the timeline and sequence of events for the scenario was reported as one of the main challenges for scenario analysis. Many of the interviewees noted that it can be difficult, especially for less experienced analysts, to understand fully how the scenario will progress and at which points the operators are required to perform certain actions. Lack of experience and knowledge of analysts can also create challenges in terms of understanding the plant systems and how these are operated in reality, to ensure that the analysis reflects a realistic "as operated" scenario, rather than how it is modeled in the PRA. Without a good understanding of the plant response and scenario progression, the analysts may not ask the right questions to get the information that they need for a realistic analysis.

Another key challenge related to the above is ensuring that the information received is accurate and trustworthy. This can be especially difficult given the usual time constraints of the analysis and the busy schedules of operators and simulator trainers at the plant. Some analysis reported that it can be difficult to get access to the most knowledgeable people because they tend to be quite busy and/or it may be difficult to get access to a number of different people to cross-check and confirm information received.

Resolution of Uncertainties or Contradictions

Many of the analysts noted that they often have to deal with uncertainty during the scenario analysis, because they are unable to collect information about all aspects of the specific scenario that is being analyzed. One interviewee noted that there tends to be more uncertainty in the analysis if the scenario takes place over a longer time window (e.g. 24 hours or longer) or if the operating instructions are not yet fully developed because, for example, the analysis is for a new plant system.

In cases like these, the analyst must make assumptions about the scenario. This can be quite typical in HRA and is acceptable, but the analysts stated that it is important to ensure that any assumptions are clearly documented so that they are transparent to the PRA analysts and the plant. Some interviewees also recommended discussing uncertainties with operators and PRA analysts as they may be able to provide the missing information.

The interviewees generally agreed that they do not often get contradictory information during the scenario analysis, but some noted that it can happen because the person providing the information may be unaware of recent changes or may lack the requisite knowledge. In this case, they noted that it is particularly important to ensure that the analyst speaks to more than one operator and, if possible, observes the scenario in the simulator to correct the contradictory information. The analyst can also discuss this with the PRA team to determine which information source is more trustworthy. Again, this should be clearly documented for transparency.

Safeguarding Against Bias in the Analysis

There is a risk that HRA analysts (and consequently the HRA itself) may become biased as a result of the information sources received during the scenario analysis. Some of the interviewees reported that, to prevent this from happening, they treat every analysis separately and always work on the assumption that every plant is different. Some of the interviewees stated that they frequently review previous relevant analyses to see what was done before, which could bias the analyst. However, they noted that, as long as the analyst only uses the previous work to enhance their own knowledge and does not directly copy from this, then it should not introduce a significant risk of bias. It is imperative that the HRA reflects the reality of how the plant is operated now.

Many of the interviewees agreed that it is possible that operators can be biased in their opinions of how the scenario might unfold. It is not unusual for operators to think that "this situation would never happen to us" or "we would never make that mistake". The interviewees noted that it can be difficult to get operators into the right mindset to be able to understand the scenario and the potential errors that could occur. Again, the way that most analysts resolve this problem is to ensure that they interview more than one operator and/or observe the scenario in the simulator.

Good Practices

The interviewees were asked about good practices that they have developed and/or implemented when conducting scenario analysis, as listed below:

- Contact the plant in advance of a visit to ask for relevant information and documentation – this will help the analyst to familiarize themselves with the plant and the scenario to help ensure they focus on the appropriate issues when they visit the plant or simulator.
- Talk to the operators and/or the simulator trainers to understand the reality of the "as operated" scenario.
- Document assumptions and any expert judgments made during the analysis to ensure these are transparent for future readers of the analysis.
- Get operating staff and the PRA team to review the final HRA report to ensure the information underpinning the analysis is correct.
- Review relevant event reports and other documented operating experience (OPEX) reports as these often provide valuable insights into previous similar events.

Desired Improvements

Finally, the interviewees were asked about improvements that they would like to see regarding the scenario analysis phase of HRA. Most of the analysts identified a need for better guidance on how to perform scenario analysis, to reduce inter-analyst variability in terms of how the approach scenario analysis.

A small number of analysts noted that there needs to be better interaction between the PRA and HRA analysts, to ensure that HRA analysts understand the context of the HRA within the PRA and to ensure that the HRA is reported in such a way that it is useful to and provides the information needed by the PRA.

Many of the analysts also reported a need for guidance on how to collect the right information to enable a better assessment of dependency later in the analysis. Assessment of dependency is generally considered to be an area of current uncertainty within HRA, with little method guidance available on how to do this, and so it is unsurprising that this has been cited as an area for improvement.

5. CONCLUSIONS AND NEXT STEPS

A total of sixteen interviews have been carried out to date to input to this study on scenario analysis for HRA. From these interviews, it can be concluded that there is widespread agreement on the importance of qualitative scenario analysis as it underpins the remainder of the HRA. It is also clear from the interviews that the quality of the scenario analysis is often dependent on the knowledge and experience of the analyst. Furthermore, because many HRA methods do not provide explicit guidance on how to perform scenario analysis, there is inconsistency between analysts' approach to this phase of the HRA which can further impact on the quality of the overall HRA.

The interviews also reinforced the importance of going to the plant and/or simulator to collect information for scenario analysis. It is clear that scenario analysis cannot, and should not, be performed in isolation or as a desk-top exercise. The input from talk-throughs, observations and discussions with operating staff, simulator trainers, and PRA analysts is essential to ensure the HRA reflects the "as operated" reality of the scenario.

The findings from these interviews will be used to develop an initial guidance document for analysts performing HRA. This will be supplemented by the findings from some more detailed case studies which are being planned at the time of writing this paper. It is intended that a workshop will be held later in the year to review the guidance with a panel of HRA analysts, and a final version of the guidance document will be issued at the end of the year.

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